Railway Signaling & Communications

JULY, 1965

Simmons-Boardman TIME-SAVER Publication

...because they're so thoroughly proved

Cymbals made by one family have been the predominant choice of top performers since 1623. Modern metallurgists—even given the proportions of metals in the alloy—say cymbals made according to the ancient formula would be as brittle as glass. "Magic," they insist, can be the only possible explanation! And the secret of the magic is shared by just three living men.

Cables look alike and may seem very simple, as cymbals do, but there *is* a difference. Quite unique among cables, Kerite has a tradition of performance likewise based on an old and secret process known but to a few! Its "magic" largely explains why so many miles of Kerite cable have already been in service for fifty and sixty years... and are still good for decades more.

Other "secrets" of Kerite longevity: manufacturing methods constantly updated... continuing research... and arduous long-term testing. No secret at all is the fact that the best proof of what cables *can* do is what they *have* done. Kerite is your best assurance of lowest-cost dependability throughout the years. The Kerite Company, 30 Church St., New York 7, N. Y.

Kerite

the cable that lasts... and lasts... and lasts

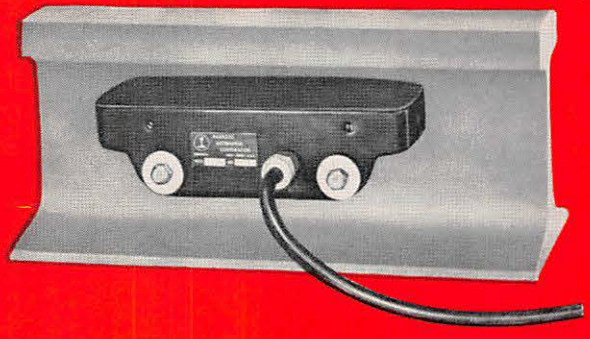
RACO MAGNETIC DETECTOR:

"Originally designed to detect the presence of railroad engines and cars at given locations —at any speed."

TODAY, through dependability and economy these applications have been earned

- ☑ Release control of Electric Switch Locks
- ☑ Track component of speed determining circuits
- ☑ To eliminate special cut sections for secondary highway crossing signal controls
- ☑ Augment basic track circuits in trap circuit design
- ☑ Detect motion and direction
- ☑ Control yard TV, or cameras
- ☑ Track component for car counters
- ☑ A series of units can detect broken flanges

RACO MAGNETIC DETECTION



RACO MAGNETIC DETECTOR
NO. MD-10

RACO PRODUCTS — ENGINEERED FOR LONG LIFE

RPI MEMBER

RACO RELAY OPERATOR
RO-12 or 24

An economical and effective non-mechanical device totally encapsulated in neoprene, the Raco Magnetic Detector employs a magnetic contactor biased by a permanent magnetic field. When the field is disturbed by a ferrous mass in the required proximity, the contactor is operated and a circuit selected through the contactor is opened.

The Raco® RO-12 or 24 volt relay operator is a solid state unit designed to match the magnetic detector to a standard signal relay. Connected between a magnetic detector and repeating relay it performs two functions. First, it lengthens in effect the operating time of the magnetic detector by about one second providing a sufficiently long pulse to the relay to enable it to become fully energized under all conditions. Secondly, the highly inductive load of the relay is removed from the magnetic detector contacts assuring long contact life.

Order through the RACO GROUP office nearest you.

THE RACO GROUP

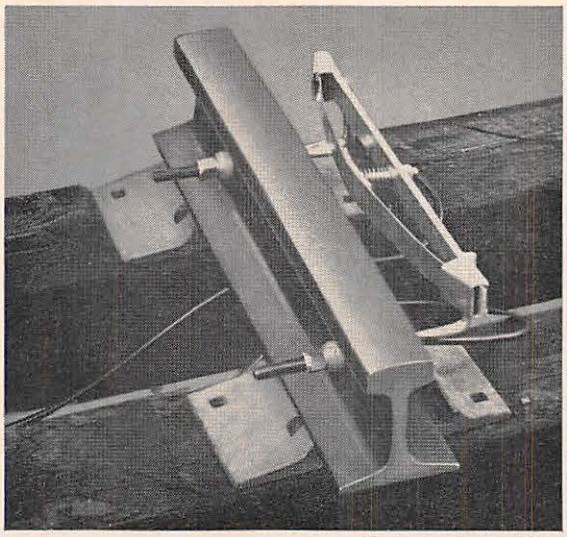
Office and Plant
TRANSPORT PRODUCTS CO.
7615 National Turnpike, Fairdale, Ky.
(Area Code 502) 774-5711

Main Office and Plant
RAILROAD ACCESSORIES CORP.
5 Tenakill Park, Cresskill, N.J.
(Area Code 201) 568-4600

Office and Plant
GRISWOLD SIGNAL CO.
700 Plymouth Ave., Minneapolis 11, Minn.
(Area Code 612) 522-6639

loose wheel detection can be

as simple as this...



Patent applied for

. . . a RACO LWD-10 sensing unit is installed on each track to detect misaligned wheels in passing and to trigger an indicating relay. The defective car can be sprayed with identifying dye or the information can be transmitted to the nearest control office for appropriate action.

economies?

The RACO loose wheel detector lends itself for application at existing hot bearing detector and/or dragging detector installations where the circuiting and telemetering can be utilized for transmitting of loose wheel information without additional cost for transmission equipment.

information?

Contact the RACO office nearest you for complete specs and information on the RACO LWD-10.

RACO PRODUCTS — ENGINEERED FOR LONG LIFE ®

GRISWOLD SIGNAL CO., Minneapolis, Minn.
RAILROAD ACCESSORIES CORP., Cresskill, N.J.
TRANSPORT PRODUCTS CO., Fairdale, Ky.

GEARED TO PROGRESS — RPI MEMBER

Over 100 corporate years of service to the railroads of North America

How to put your most remote station only an arm's length away

Stromberg-Carlson's Message Circuit Dialing System provides fast, unattended, economical communication, to every remote location on your existing facilities. In addition to complete integration of message lines, it offers many other benefits, such as:

- All-tone system permits dialing over 25 db line without repeaters.
- Type 60 selector system utilizes your present equipment and updates it for dialing.
- Equipment mounts on standard relay racks for easy installation.
- Provision is made for message stations to dial direct into a PBX for connecting to a local station; also for tandem dialing to a distant station on another message circuit.
- PBX stations can signal any message station by dialing assigned code or digits.

To get complete details, address your inquiry to the Industrial Sales Dept., 124 Carlson Rd., Rochester, New York 14603.

STROMBERG-CARLSON CORPORATION

RAILWAY SIGNALING and COMMUNICATIONS

July 1965
Vol. 58 No. 7

Railway Signaling & Communications

ATO Under Test in Several Countries 13
Interest in automatic train operation runs high with tests underway in California.

ATO Developed for Tokaido Line 14
Japanese develop notch programming techniques for ATO.

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Automatic pilot developed to run subway trains in Stockholm.

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System has audio frequency track circuits for running commands.

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EDITOR'S CORNER

Report to Readers

A couple of months ago we mailed letters to 660 subscribers asking them to give us their opinions of our April issue. This survey is the same as the one we conducted on the January issue (see page 46 June RS&C), except that the letters were sent to different subscribers. With two more surveys—July and October issues this year—we expect to have reached all of our railroad subscribers.

The 110 replies indicated a response of about 17%. As in earlier surveys we asked for three types of ratings: Very Good—well written and helpful; Satisfactory—but could be better; and Not Interested.

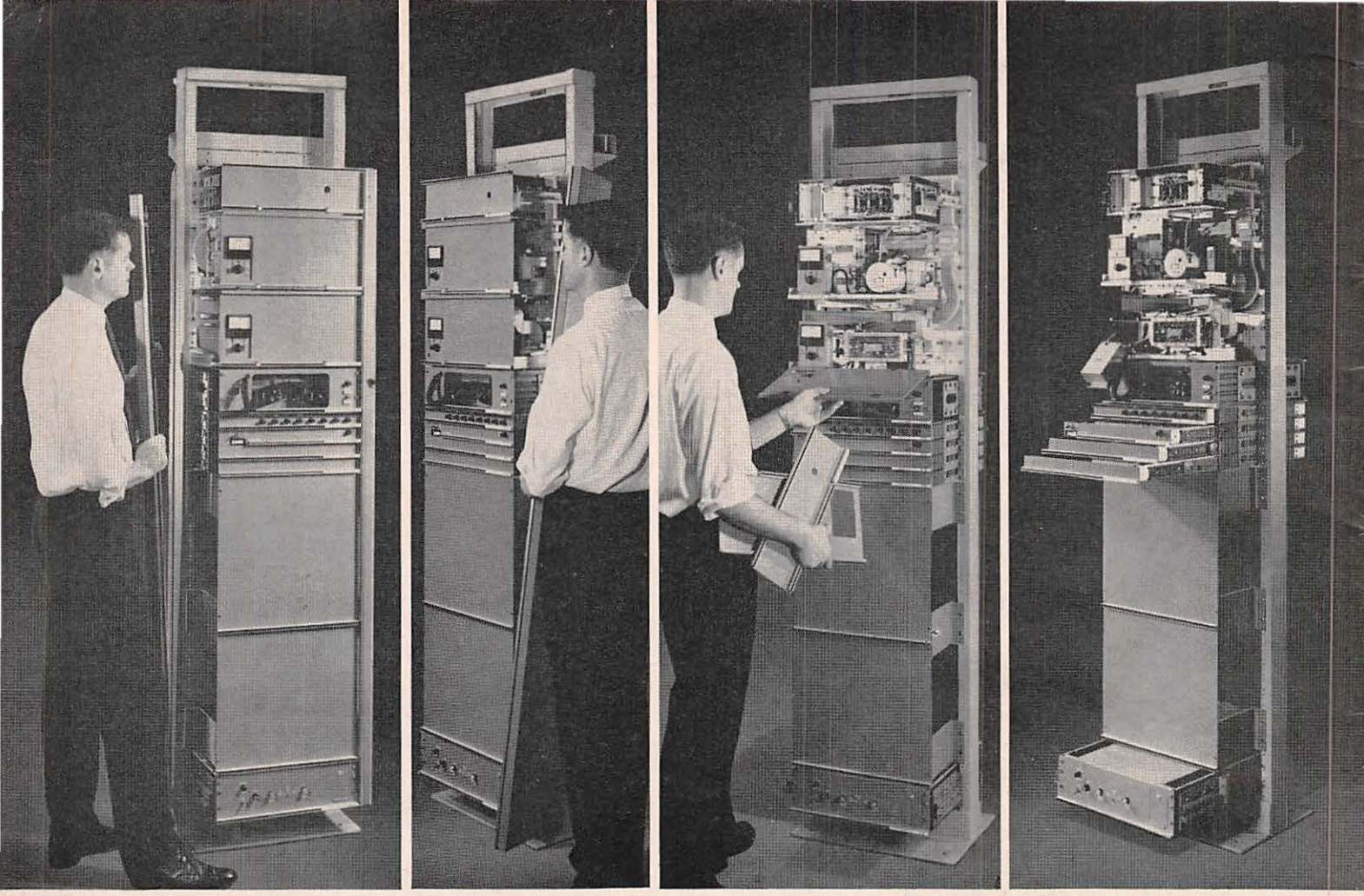
Highest readership in the very good category went to the ICC wreck report (page 18), which weighed in with a 74%. Reporting on the AAR and RLEA replies to the Examiner's report on the signal RS&I rated 58% in the very good standing. Replies from 19% of the readers rated the wreck article satisfactory. Seven percent were not interested in this article. Twenty-six percent found the RS&I article (page 22) satisfactory and 16% were not interested.

The railroad microwave article (page 13) received the following scores from readers: very good—55%; satisfactory—28%; and not interested —17%. The Editor's Corner earned the following ratings: very good—64%; satisfactory—32% and 4% were not interested. The book review on the Fundamentals of Relay Circuit Design scored very good with half of the readers replying, while 34% found it satisfactory and 16% were not interested.

Everyone likes News Briefs, rating it either very good (53%) or satisfactory (47%). Railroad personnel, product news and supply trade news drew very good ratings of 56%, 57% and 49% respectively. Satisfactory ratings were 41%, 42% and 46%, respectively. The not interested ratings were 3%, 1% and 5%, respectively.

Bob McKnight

P.S. Note our new address.



Breakaway design for immediate accessibility, from the only manufacturer who offers a 5-year warranty on microwave radio

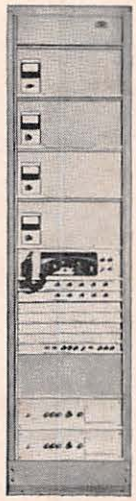
Raytheon's KTR II is the most advanced remodulating microwave radio in the industry.

The new KTR II is Raytheon's response to the communication engineer's demand for unmatched equipment reliability . . . plus a sharp departure from past concepts of equipment accessibility.

The entire rack, for example, can be opened for complete front-access in just 17 seconds. For in-service test and adjustment, magnetic latches and pull-out drawers offer easy access to all functional modules. Each module is contained in its own RAYSHIELD* container, and can be easily and quickly replaced. This exclusive construction technique gives added shielding and permits access to individual circuits without interrupting service.

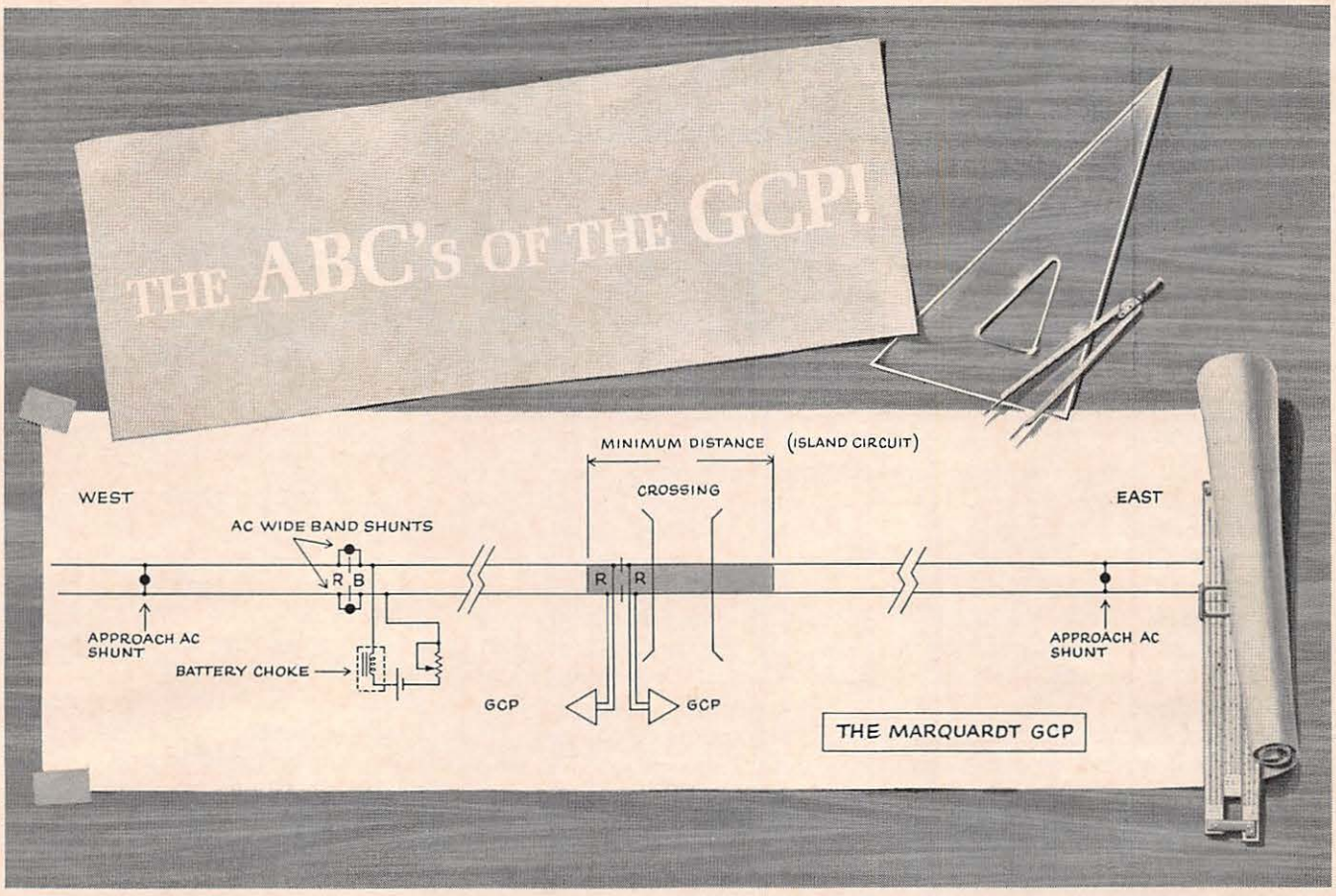
The KTR II is one of the new solid-state equipments produced by Raytheon, a leading supplier of quality microwave radio equipment since 1948.

**Raytheon's designation for its module packaging technique.*



For complete information write: Equipment Sales Manager, Raytheon Company, CADPO, 1415 Providence Turnpike, Norwood, Mass.

RAYTHEON



This is how the Marquardt Grade Crossing Predictor (GCP) provides fail-safe crossing protection and reduces highway traffic delays.

The Marquardt GCP is a solid state analog control system, designed to compute speed and position of an approaching train, predict its arrival at the crossing, and activate the warning system.

The train is approaching the crossing from the west. The Grade Crossing Predictor number (1) senses an impedance corresponding to the distance from the crossing to (A) the approach shunt. As the train enters the GCP circuit, it acts as a "moving" shunt, reducing the impedance as it approaches the crossing.

Since each GCP is constantly measuring the impedance level as well as the rate of change, it can predict the train's arrival at the crossing and activate the protection system at the pre-selected warning time. Uniform warning time on constant speed trains is thus provided regardless of the train speed.

Should the train stop in the approach, the GCP no longer senses a change in impedance. An already-activated warning system will be cleared within seconds. If the warning system was not activated, of course, nothing happens. As the train resumes its approach to the crossing, the GCP again senses the impedance change and immediately activates the warning system. The warning devices will be deactivated as the last trucks clear the minimum distance (island circuit). If the train reverses direction after having gone through the crossing, Grade Crossing Predictor number (2) takes over. Highway traffic is resumed with minimum delay.

BASIC FEATURES OF THE GCP SYSTEM

■ *Note that only two insulated joints (B) are actually required for GCP operation. These serve to isolate one approach from the other, establishing a defined circuit from the joints to the approach shunt (A).* ■ *Where other insulated joints exist in the GCP approach circuit, AC wide band shunts (C) are used to bypass these joints, thus providing a complete circuit down one rail, through the approach shunt, and back the other rail to the GCP. The shunts are 80,000 microfarad capacitors which block the DC signal. These are encapsulated and waterproofed for burial below the frost line alongside the track.*

■ *Where a battery is connected to the track, a battery choke (D) is installed in series with one of the battery leads. This prevents the AC signal from shorting through the battery. The choke has a high impedance to AC, and because of its low resistance (0.25 ohms), it has little effect on the DC circuit.*

■ *The approach AC shunts (A), connected from rail to rail, complete the GCP circuit. They are located at a distance from the crossing corresponding to maximum train speed and required warning time.*

■ *Built-in self-check system insures fail-safe GCP operation. The system simulates an approaching high speed train every 4.5 seconds, even when a train is on the track. Should a malfunction occur, the warning system is immediately activated.*

Write or call your Marquardt representative today. Ask him to show you how the Grade Crossing Predictor can meet your specific crossing protection requirements.

RAILROAD PRODUCTS MEMBER

POMONA DIVISION

THE Marquardt CORPORATION

Industrial Products Department • 2882 Metropolitan Place, Pomona, Calif.

SALES OFFICES: One Old Indian Head Rd., Commack, N. Y.
Phone: 516-266-6383 / 310 S. Michigan Blvd., Chicago, Ill. Phone: 312-922-1334

NEWS BRIEFS

• ATLANTIC COAST LINE will soon be operating 10 new GE and 14 new EMD diesel-electric locomotives with intermittent inductive train control equipment that was furnished by General Railway Signal Co.

• BALTIMORE & OHIO has ordered type KM2 CTC equipment from General Railway Signal Co. to handle a 17-mile section of double track between McKenzie-Miller to Orleans Road, W.Va.

B&O has ordered nine hotbox detectors from GRS of which eight will be installed between Akron, Ohio and Chicago, Ill. at Homer, Tiffin, Standby (2), La Paz, Alida, Bascom and Cromwell. The ninth unit will be installed on the Cumberland division.

• BOSTON & MAINE's application for authority to discontinue the operation of automatic cab signal equipment between West Cambridge and East Deerfield, Mass., 99 miles, has been denied after a hearing held by examiner Henry J. Vinskey.

• CHICAGO TRANSIT AUTHORITY awarded a $702,480 contract to General Railway Signal Co., to furnish an automatic train detection and over-speed control system using cab signals and audio frequency track circuits on the Lake street line. By use of wayside equipment, speed commands are transmitted through audio frequencies to coils mounted in front of train wheels. The coils and car logic interpret the speed commands and actuate cab signal equipment, which will indicate to the motorman prevailing conditions of the track ahead and maximum permissible speed. If the motorman does not respond to the visual and audible signals within the allowable time, the train will automatically stop. On curves and in certain other areas along the route, the system will restrict the speed of trains to a predetermined maximum which, if exceeded, will result in an automatic stop. CTA will install the wayside and cab equipment on 70 two-car units of rapid transit cars.

• DETROIT, TOLEDO & IRONTON has ordered seven Grade Crossing Predictor units for highway grade crossing control from Marquardt Corp.

• IEEE Vehicular Communications Conference: A call for papers to be presented at this conference, to be held Dec. 2-3, 1965, at the Sheraton-Park hotel in Washington, D.C. is now under way. All phases of vehicular communications and related topics are to be discussed. The author of a paper will be allotted 30 minutes for presentation which will include a 5-10 minute period for discussion. Persons wishing to present papers are requested to submit abstracts of not less than 250 words (500 preferred) to W. F. Biggerstaff, Papers Committee Chairman, USFS Electronics Center, ARC, Beltsville, Md., 20705. Abstracts must be in by July 15.

• INTERSTATE COMMERCE COMMISSION'S division 3 has upheld Examiner Henry J. Vinskey's hearing report and order concerning safety regulations pertaining to track motor cars and push trucks (RS&C March 1965, page 10). At the end of the rules, the following note is appended: Sections 131.25 and 131.26 are applicable only when the vehicles governed thereby are coupled together and moved together. Division 3 made one change in approving the examiner's report and order. The footnote under Section 131.26 (a) regarding hand brakes is deleted.

• KANSAS CITY SOUTHERN has ordered two GCP units and four electronic track circuit equipments from Marquardt Corp.

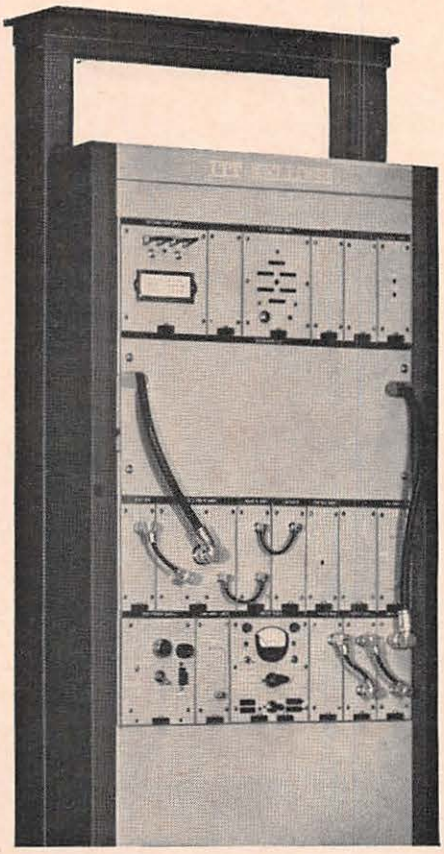
• LEHIGH VALLEY has ordered type H CTC equipment from General Railway Signal Co., for installation at Packerton Jct., Pa. Equip-

(Please turn to page 10)

This Was News 50 and 25 Years Ago

The Signal Engineer, July 1915. Norfolk & Western installs AC block signals on 28 miles of line between Bluefield, W.Va., and West Vivian. The change over from DC signaling was caused by electrification of the line through Elkhorn tunnel. Single-phase, 25 cps power is used for traction and 60 cps power for the signal system. The AC semaphore type signals are mounted on the bridges supporting the overhead trolley line.—Union Railroad of Baltimore, handling PRR trains in vicinity of Union Station, installs automatics and interlockings on 4-track line over which there are 300 movements daily.—New York, New Haven & Hartford will spend $600,000 to install automatic block signals on its 4-track mainline from Stamford, Conn., to Woodlawn, N.Y., 20 miles.

Railway Signaling, July 1940. Bessemer & Lake Erie installs train telephone system that uses rails for transmission medium of 5.7 kc current between locomotive and caboose of a freight train. On transmitting end, connections are made to car trucks and at the receiving end, the 5.7 kc signal is picked up inductively by car-carried coils mounted over the rails. The new train communication system is in operation on 128 miles of line between Albion, Pa. and North Bessemer yard.—Louisville & Nashville installs remote control interlocking at Knoxville, Tenn., which includes a crossing of two single-track lines with special provisions to facilitate switching.—Atlanta Terminal replaces old interlocking plants with new equipment. Complete electric locking installed; AC-DC track circuits for reliable shunting; and change-over made under traffic with no train delays and with full interlocking protection. Traffic at this Atlanta, Ga., passenger station totals about 500 train movements and switching operations daily. **RS&C**



Your VTVM uses three times as much power as this K260 Solid State Microwave.

When you transmit 120 voice frequency channels with only one-third the power required for your VTVM, that's making a little do a lot.

But the K260 does it easily. Because it's an exceptional microwave system.

In addition to using only 35 watts (at —24VDC, —48VDC, or 115 VAC) for 120 channels, it's very compact.

A full terminal weighs approximately 60 pounds and occupies only 14 spaces on a 19-inch rack.

And because the K260 is compact, uses very little power, and has a variety of power options, it is ideal for temporary or emergency communications as well as permanent installations.

Features you'll particularly appreciate in the K260 are its built-in service channel, modular construction for simple maintenance, and built-in metering for testing.

The K260 operates with an output power of 1 watt in the frequency range of 1700 Mcs to 2300 Mcs. Baseband impedance is 75 ohms, unbalanced.

To fully appreciate the design and workmanship that go into the K260, it is really necessary to examine the inside of the unit very carefully.

So look inside one first chance you get.

Or write to Dept. P for descriptive literature.

That's the next best thing.

ITT Kellogg Transmission Products, 2912 Wake Forest Road, Raleigh, North Carolina.

ITT KELLOGG

(Continued from page 8)

ment will permit joint operation of Jersey Central and LV trains over 1½ miles of track.

• LOUISVILLE & NASHVILLE's application seeking relief from the requirements of Section 136.410 of the RS&I to the extent that it be permitted to remove electric locks from certain switches and crossovers on its Evansville division without reduction in the maximum authorized train speeds of 25 mph has been granted, after a hearing, by Examiner Robert R. Boyd. The switches and crossovers are hand-operated and in CTC territory.

• MILWAUKEE ROAD has ordered four Grade Crossing Predictors from Marquardt Corp., for the control of highway grade crossing protection equipment.

• MISSOURI PACIFIC LINES ordered six GCP units for the control of highway-railroad grade crossing protection equipment from the Marquardt Corp.

• NORFOLK & WESTERN will spend $13.5 million for an electronic, automatic retarder classification yard at Bellevue, O. The road will install CTC on 145 miles of line between Fort Wayne, Ind., and Danville, Ill.

• NORTHERN PACIFIC has ordered type K CTC equipment from General Railway Signal Co., for controlling 17.5 miles of line between Frenchtown and Missoula, Mont. Also, NP ordered a type K CTC system from GRS to be installed on 60 miles of single track from Kootenai, Ida., to Tuscor, Mont. The existing Traffic Master machine at Spokane, Wash., will be expanded to handle the 10 additional control points.

• FLORIDA EAST COAST has ordered eight sets of long-shunt, electronic overlay track circuit equipments from General Railway Signal Co., for installation at highway crossing protection installations.

• INDIANA HARBOR BELT has ordered 15 GCP units from Marquardt Corp., for the control of highway grade crossing protection equipment.

• PENNSYLVANIA has ordered one set of Train Multiple Unit-er equipment from General Railway Signal Co. TMU is a locomotive-mounted, computer-electronic system that automatically controls mid-train locomotives without need for communication with the lead locomotive or the wayside. The TMU equipment senses coupler tension and compression to maintain a constant ratio between coupler horsepower and train tonnage over any terrain.

• SANTA FE has ordered 11 Grade Crossing Predictor units for highway grade crossing control from the Marquardt Corp.

• SOUTHERN has ordered type K2 CTC equipment from General Railway Signal Co., for installation between Gastonia, N.C., and Worley, S.C., about 81 miles. The existing control machine at Greenville, S.C., will be expanded to control 13 additional locations. About 40 miles of second main track will be removed. GRS Trakode will replace existing line circuits, and 30 sets of long-shunt overlay track circuits will be installed for highway crossing protection. Series overlay track circuits will be provided for switch lock release.

SOU has ordered TMU equipment from GRS for automatic control of a mid-train locomotive.

Type K2 CTC has been ordered by SOU from GRS for control of the access line to the new 50-track classification yard, now under construction at Macon, Ga. The control machine in the yard office will control the 8-mile line between North Macon and CofG Junction, Ga. Trakode will be used instead of line wires to control the CTC signals. Model 5C mainline electric switch machines will be installed to handle yard switching at the pullout tracks.

George W. Kearney
Baltimore & Ohio

Jack E. Rupp
Gen. Railway Signal

• SOUTHERN PACIFIC LINES has ordered 69 GCP units and 27 electronic track circuit systems from Marquardt Corp.

• UNION PACIFIC has ordered an NX route-type relay interlocking system from General Railway Signal Co., for installation at Omaha, Neb. The machine will control 150 signals and 112 switches to handle traffic of seven other railroads in addition to UP trains. Controls will be also arranged for call-on, fleeting moves, and switching signal manipulation.

UP has ordered 18 sets of GCP equipment from Marquardt Corp., for control of highway grade crossing protection equipment.

Railroad Personnel

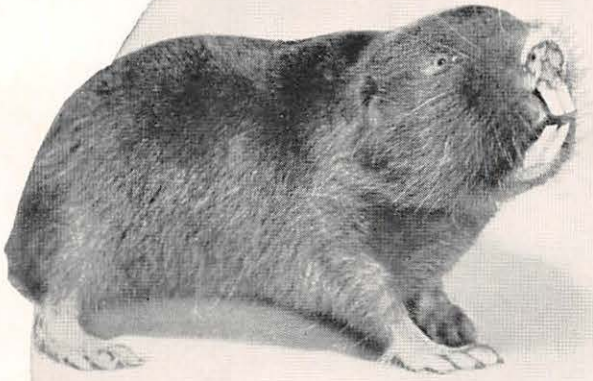
• BALTIMORE & OHIO: **George W. Kearney,** deputy communications engineer, has been promoted to communications engineer. Mr. Kearney was born on Sept. 13, 1925 at Pittsburgh, Pa. A graduate of the Bliss School of Electrical Engineering, he joined the B&O in 1947 as a telephone maintainer at Pittsburgh. In 1952, Mr. Kearney was appointed assistant communications engineer, and three years later promoted to communications engineer. Subsequently he advanced to senior engineer communications and in 1963 was appointed deputy communications engineer.

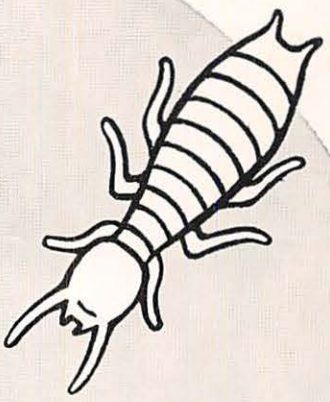
• CANADIAN NATIONAL: **A. E. Brown,** signal supervisor, Assiniboine area, Winnipeg, Man., is appointed signal supervisor for the Winnipeg area.

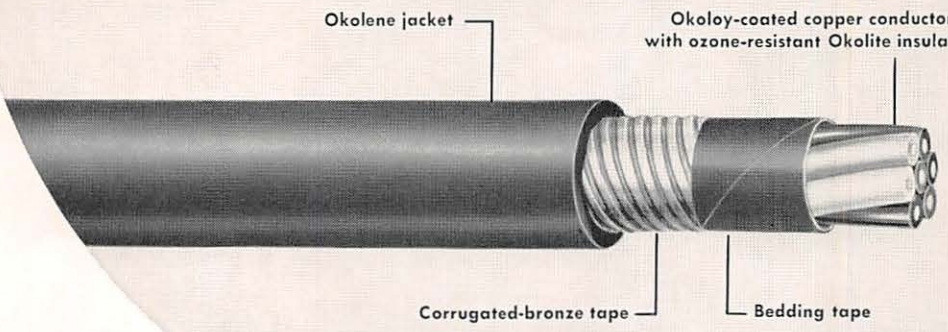
• ERIE LACKAWANNA: **W. E. Bell,** signal engineer, Cleveland, is appointed chief signal engineer, succeeding **Frank Youngwerth,** resigned. **George I. Molusky,** signal supervisor, Hornell, N.Y., appointed signal engineer succeeding Mr. Bell. **James J. Mahoney,** assistant signal supervisor, Huntington, Ind., appointed signal supervisor at Hornell. **Harry W. Klein,** foreman signal

(Please turn to page 33)

Protect against pests and mechanical damage







Use Okonite CM-PF corrugated-bronze armored cables

The corrugated-bronze tape in Okonite CM-PF signal and control cable puts an end to damage caused by termites, gophers, other rodents, small animals and insects. The corrugated construction provides unusual compressive strength to give CM-PF cable excellent resistance to crushing and mechanical damage. Maintenance costs go down . . . circuit security goes up when you install this versatile railroad cable.

Resistance to pests and unusual compressive strength are only two reasons why CM-PF cables are used by so many railroads for signal and CTC control circuits, communication circuits, track wire, power and lighting circuits.

For a full story on this CM-PF railroad cable, write for Bulletin 1121-B, The Okonite Company, Passaic, N. J.

Here are some other CM-PF features:

- Resists: Corrosion, Moisture, Weather.
- Provides shielding against faults and electrical pick-up from adjacent lines and serves as a positive ground.
- Suitable for direct burial, aerial, rack or duct installations.
- Provides fire barrier.

OK-139RP

OKONITE
RAILROAD CABLES
THE OKONITE COMPANY
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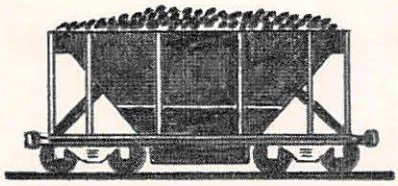
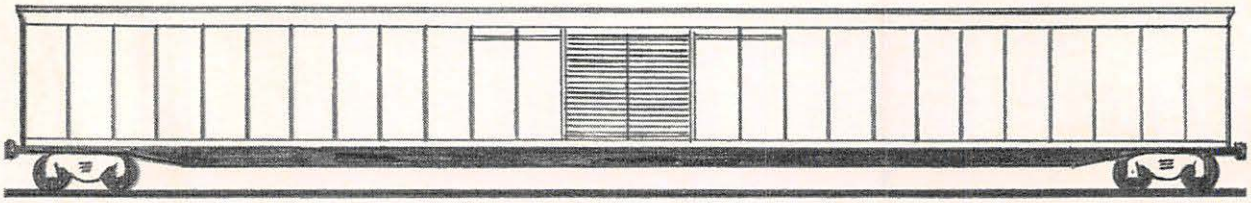


SHORT CARS



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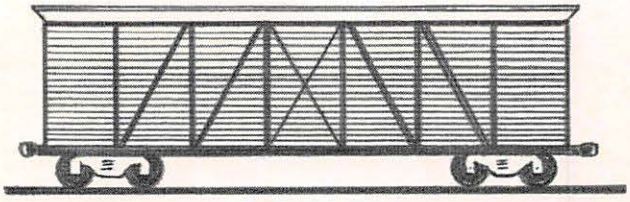

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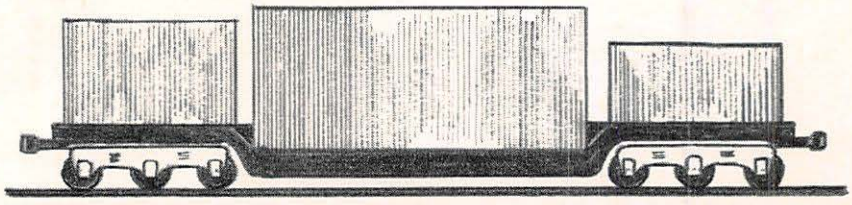

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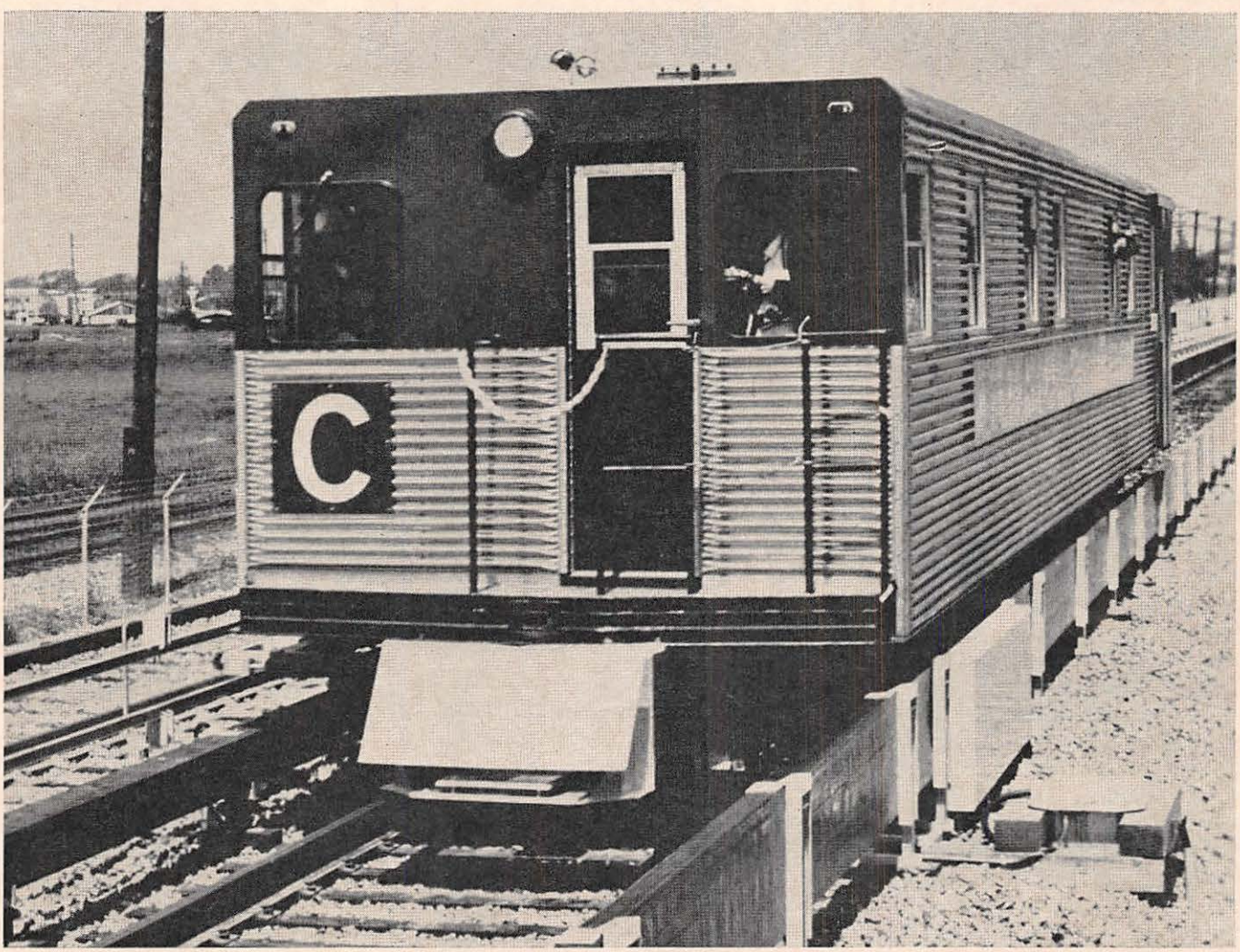


Laboratory car "C" of the San Francisco BARTD is now running on a test track near Concord, Calif.

Japan Sweden England test ATO

Automatic train operation is in the forefront of signal news. Of interest is the test track program of the San Francisco Bay Area Rapid Transit District. On May 12, laboratory car "C" (above) made a run under complete automatic operation on the test track near Concord, Calif. This brief test of ATO was made using equipment of General Railway Signal Co. Further tests will be conducted with two other test cars and with equipment of General Electric, Westinghouse Air Brake and Westinghouse Electric. On the following pages of this issue are three articles dealing with ATO installations in Japan, Sweden and England.

AUTOMATIC TRAIN OPERATION-I

ATO developed for Tokaido Line

Automatic railways was the subject of a convention held in London, England last fall. Sponsored by the Institution of Mechanical Engineers, the conference dealt with automatic train operation and related topics. Through the kind permission of the IME, we abstract herewith three paers from the conference. The first paper deals with automatic train operation by program control. Its authors are T. Ito and H. Ebihara of the Japanese National Railways. A second paper by O. Kekonius and N. O. Kallberg of the Stockholm Sparvagar deals with an automatic pilot for subway trains in Stockholm, Sweden. R. Dell, chief signal engineer and A. W. Manser, chief mechanical engineer, London Transport Executive, describe the automatic operation of trains on that facility.

Following is the paper on ATO on the Japanese National Railways (other abstracts begin on pages 18 and 24 of this issue):

The aim of notch programming is to have a train run automatically in conformity with the given train diagram. According to the distance and location of each operating section, the time, the speed and the notch position of the train are memorized in the equipment as a program. The train is made to follow this program mechanically.

The feature of this system is that the notch position N_p for each distance and location is memorized. By specifying a notch position, the turning effort of the traction motor is defined and the train runs at a speed adjusted to the running resistance. This means that, if conditions are the same, the speed remains constant. In this system though the notch position is unaltered, operating conditions change with the trolley voltage, the load of the train and running resistance, and the adjustment necessary will be made, as explained later, after being detected by the time delay in the operation of the train. However, the equipment will be kept simple because all direct instructions affect only the notch positions.

After the determination of a standard program, the problem of how to adjust the time lag detected in actual operation in order to secure on-time operation will arise. Simply speaking, the procedure is to modify the notch position by the amount proportional to the time lag Δt between the programmed time t_p and the actual time. t. That is,

$$\Delta N = K_1.\Delta t \quad . \quad . \quad . \quad . \quad (1)$$

The operating notch N is instructed with $N = N_p + \Delta N$. However, it is better to regard this ΔN as a function of the speed difference Δv between the programmed standard speed v_p and the actual speed v as well as of Δt mentioned above. This is because, when a train is delayed, it is operated by raising the notch in order to recover the delay. Suppose the train has recovered its delay at a certain point, the train speed will remain higher than the programmed speed because of its recovery operation with the notch raised. The train will keep running at a higher speed than the programmed one for a time though the notch is returned to the programmed position, resulting in the shortening of running time below the programmed one. Hence, speed difference Δv will mean a recovery capability and equation (1) can be modified as follows:

$$\Delta N = K_1.\Delta t - K_2.\Delta v \quad . \quad . \quad . \quad (2)$$

where the coefficients K_1 and K_2 were determined by electric computer from the results of simulation of the characteristics of electric railcars for the New Tokaido Line.

In Fig. 1 is shown the block diagram of the notch program system. Different kinds of program are as follows:

(1) v_m Maximum restrictive speed.
(2) v_p Standard running speed.

(3) N_p Standard notch position for operation.
(4) N_m Maximum notch position for operation.
(5) t_p Standard running time.
(6) S_p Distance and location where instructions should be executed.

These programs are punched on the tape, read by the tape reader and stored in the device. When the train reaches a given point S_p, the difference Δt between the programmed time and the actual time, and the difference Δv between the programmed speed and the actual speed are calculated, thereby yielding the amount of notch change according to equation (2). This amount is added to the standard notch position and the instruction on the notch to be applied is delivered within the limit of the maximum notch position possible at that point. If the speed exceeds the maximum restrictive speed v_m at any point, a braking instruction is delivered.

The running distance is measured by means of the rotation of the axle. But this will not indicate the accurate distance. Therefore, wayside facilities are installed at regular intervals and the value obtained from axle rotation is adjusted when the train passes these points.

In the speed programming system, no programming is made on the basis of the notch position, but distance S_p, speed v_0 and time t_p are programmed and they are compared with the actual distance S, speed v and time t. The train is automatically controlled so as to keep these programmed and actual values the same as that mentioned in the previous section and its block diagram is shown in Fig. 2.

The required speed for a given running distance can be calculated beforehand according to the conditions of the track and the train diagram, and is stored in the tape in the form of an S and v program. This tape is moved at every unit distance the train has run, and the standard speed v_0 for the distance S is obtained. In sections where the speed is restricted by track conditions, the maximum speed v_m for the distance S is programmed so as to restrict the instruction speed.

On the other hand, the required time t_0 for the distance S is determined by the train diagram and is stored in the tape in the form of S and t. This is compared with the actual time t_r and the difference Δt is detected, so that the instruction speed signal Δv may be delivered accordingly. When the train is delayed it is for increased speed, and when going too fast for retarding. Eventually instruction speed v_r is given as $v_0 \pm \Delta v$ so as not to exceed the restrictive speed v_m. By so doing, punctual operation is made possible with automatic adjustment for such outside disturbances as change of running resistance and line voltage.

When the required speed v_r is dispatched to the train, it is compared with the actual running speed v, and must be controlled to correspond with v_r. For this, many speed control systems are possible. The simplest is to have v_r and v in terms of voltage for the following arrangement: $v_r > v$ for power running: $v_r =$

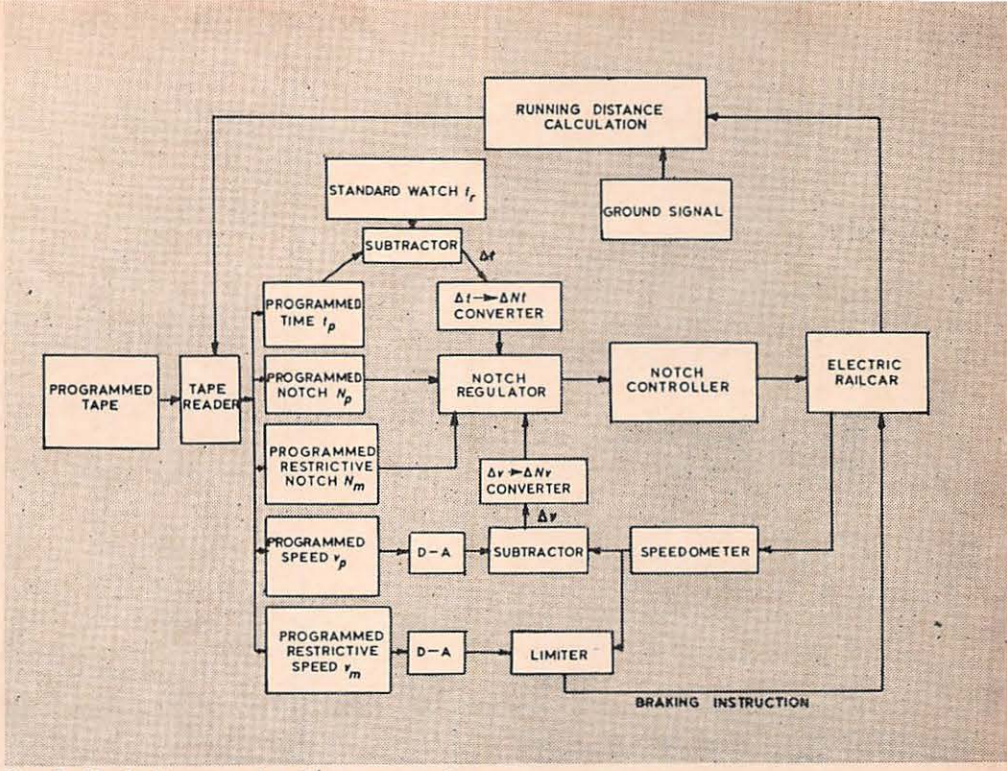


Fig. 1—Block diagram of notch programming.

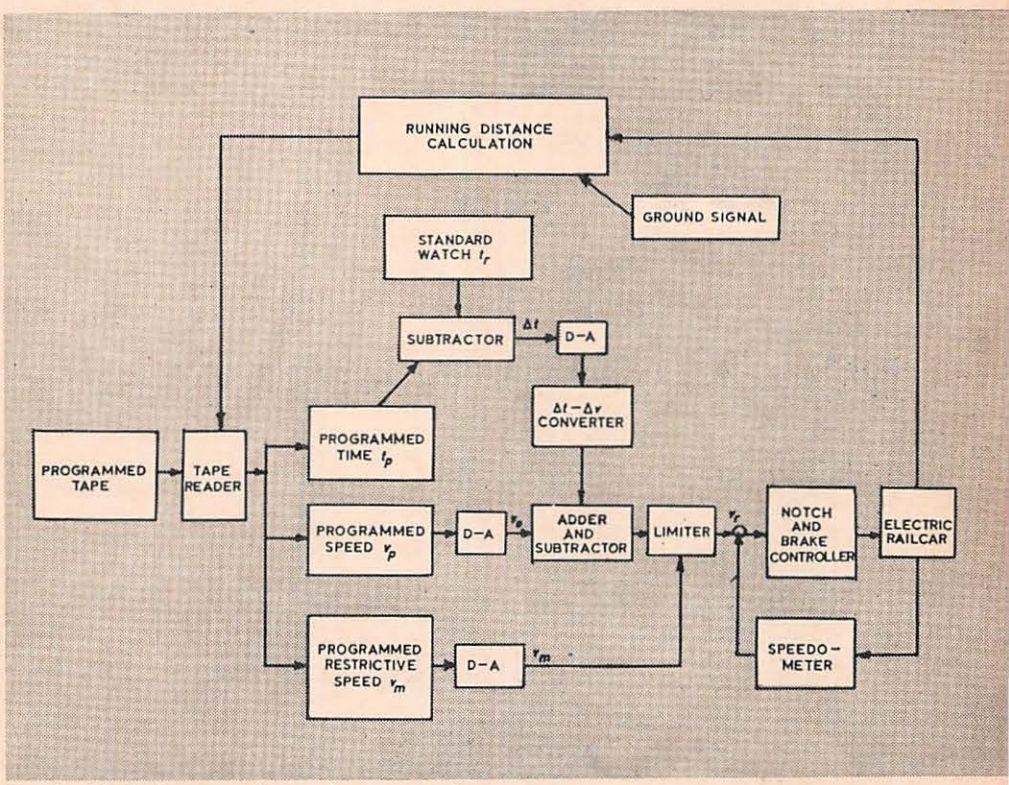


Fig. 2—Block diagram of speed programming.

v for coasting, and $v_r < v$ for braking. However, in the case of an AC electric railcar train, with many powering notches for various speeds and capable of selecting any one of the notches, it is possible to adopt the ordinary speed control system, under which the voltage for $v_r - v$ is amplified to select the right notch, and to have v conform with v_r to an appreciable accuracy.

What is shown in the speed controlling parts given on the right-hand lower side in the block diagram of Fig. 2 represents the improvement made to reduce the off-set. It is also possible to use the PID controller for speed control, and we have made experiments with this also.

Though it is possible to operate a train automatically as described, one of the most difficult aspects is to stop a train accurately, without impairing the riding comfort, at the prescribed point along the platform. It was to attain this objective that the following device was evolved. The principles of the device are as follows.

A signal is received from the ground installation at a certain distance away from the prescribed spot so as to create in the cab equipment a standard brake curve showing the relationship between speed and distance, as shown in Fig. 3. The end point of the curve indicates the desired halting point. The train then stops accurately at the prescribed spot by controlling the braking according to the curve so made up. There are many ways of making up the curve and controlling the braking, but we have a simple and accurate device completed for use.

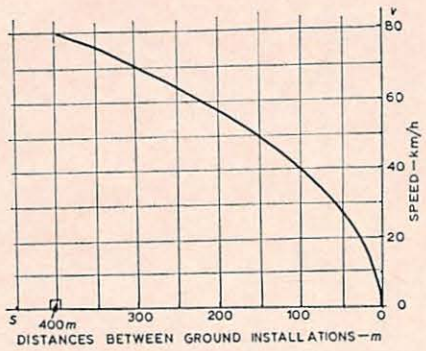


Fig. 3—Standard retardation curve.

In 1962 prototype control equipment for two different kinds of program control and automatic train halting apparatus as mentioned above were manufactured, and actual tests were carried out on the test run section in March and August 1963 on the new Tokaido Line. Examples of running curve showing the test results are given in Figs 4-6. Figs 4 and 5 indicate the distance-speed curve in test runs. The gradients in the section and the aggregate distance from Tokyo are also shown. Shown on the lower part is the difference between the programmed time and the actual opening time during the test. Fig 6 indicates the operating curve when the PID controller is used in speed control alone. Through these tests it was proved that automatic operation would attain good performance as expected. The automatic stopping device works well, the error being less than ±30 cm from the prescribed spot, and the train stopping without giving any discomfort to the passengers aboard. In the future the equipment will be further improved, primarily in the speed programming system, and the automatic braking apparatus refined to implement the automatic operation perfectly. **RS&C**

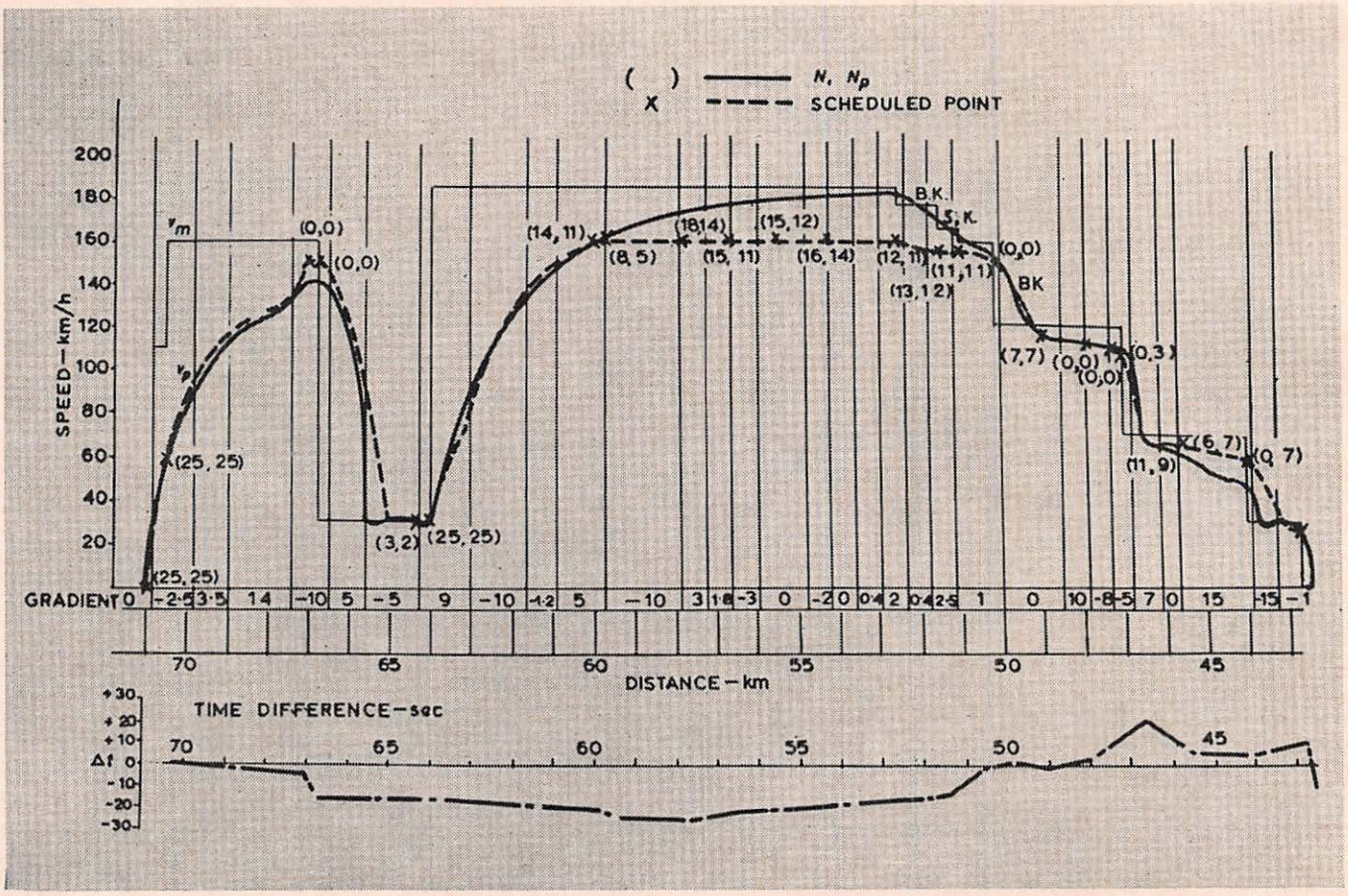


Fig. 4—Result of an actual test in notch programming.

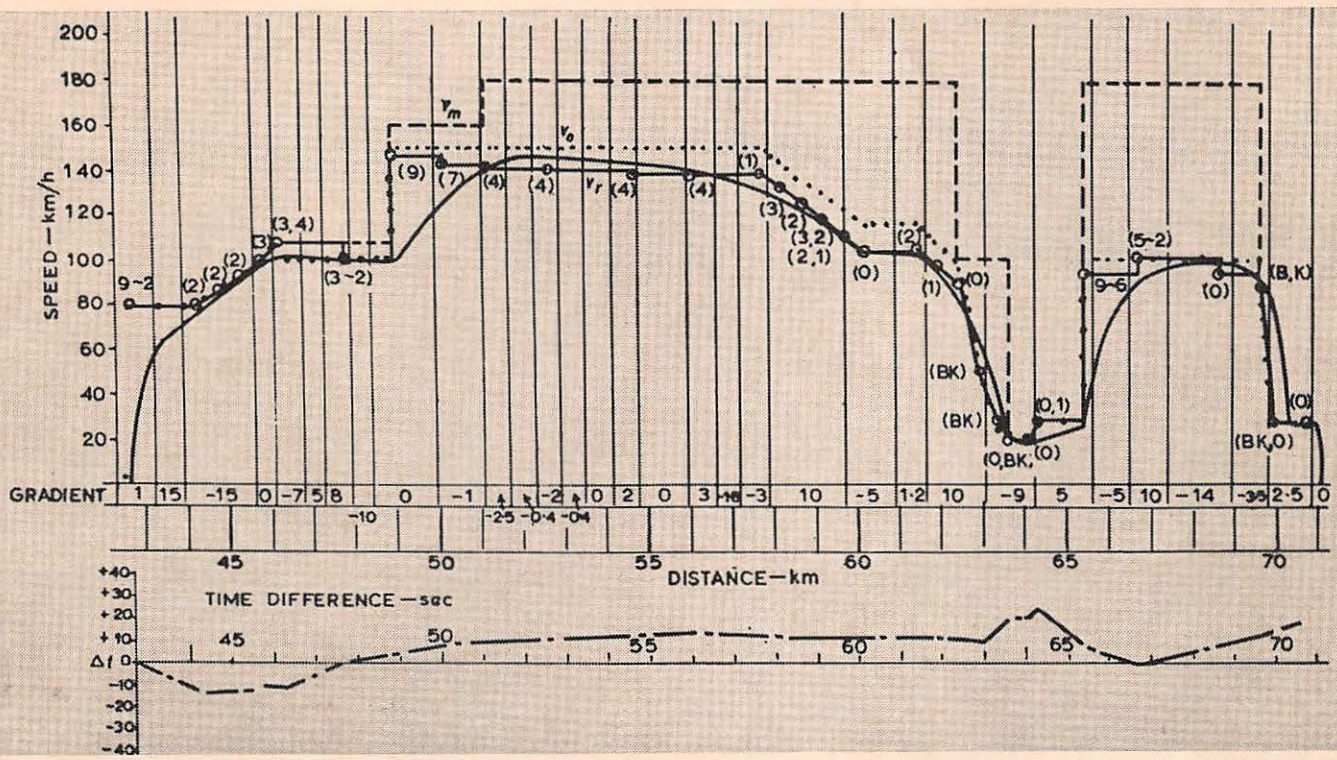


Fig. 5—Result of an actual test in speed programming.

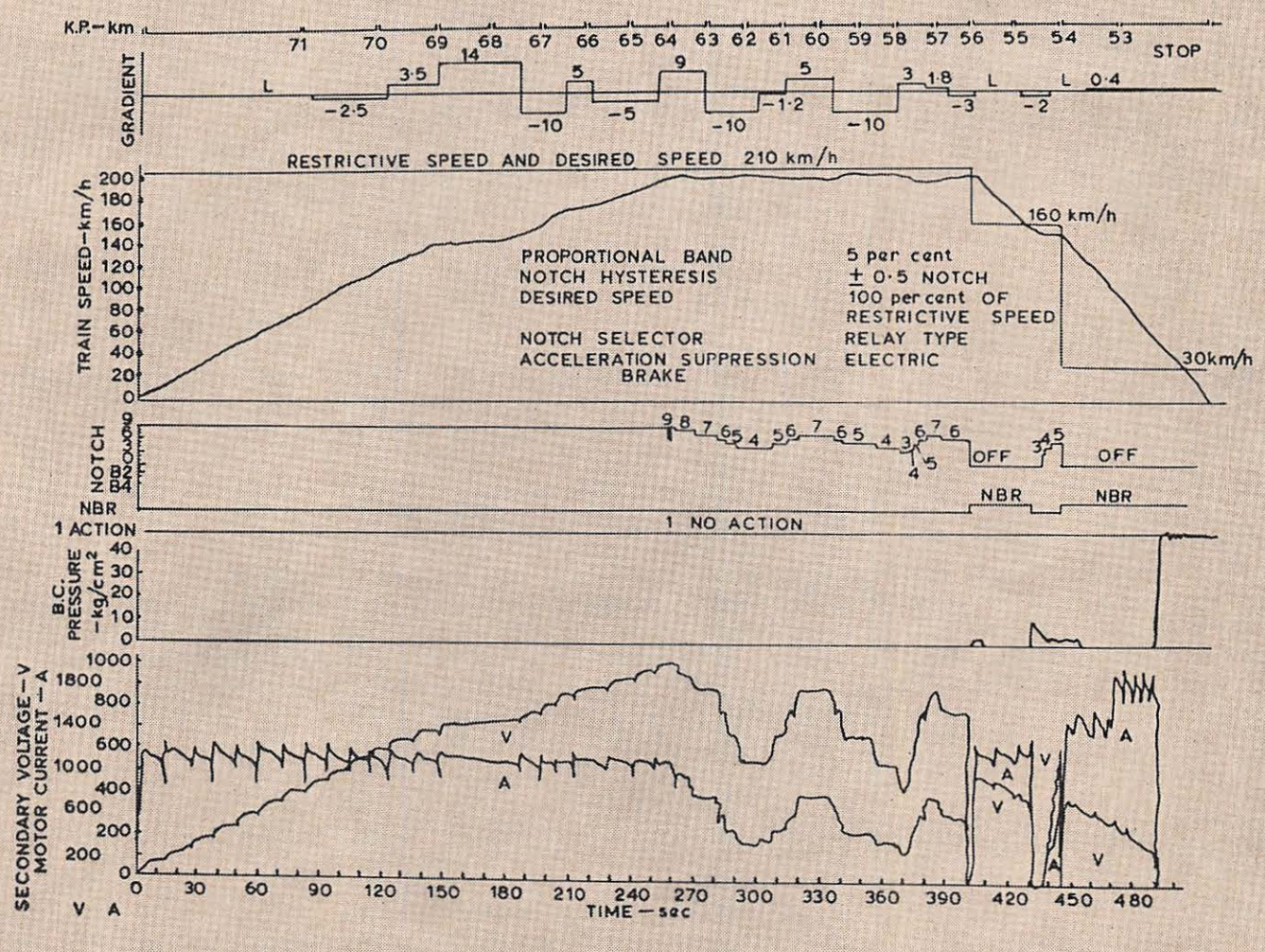


Fig. 6—An example of a running test of the automatic train speed control device.

Automatic pilot developed to run subway trains in Stockholm

The automatic pilot is capable of normal driving on an ordinary track in such a way that it starts the train as soon as the guard has closed the doors and given the departure signal. Before reaching the next station the automatic pilot cuts off the power, applies the train brakes and brings the train to a halt at the desired stopping point. Between the stations the automatic pilot in conjunction with a human pilot takes into consideration the different aspects which the ordinary cab signal equipment of the underground system may show and adapts the speed of the train to the signals.

The automatic pilot is provided with two different programs, a rapid run intended to be used in rush-hours, and an economic run intended to be used during off-peak hours when a somewhat longer but power-saving running time between the stations will be compensated by shorter **stops.**

The automatic pilot, however, is *not* able to perform any form of shunting or to drive when the most restrictive cab signal aspect L, i.e. a maximum speed of 9 mph, is given. In such cases the driver has to take over by turning a special switch from the 'automatic' to the 'manual' position.

A characteristic feature of the automatic pilot is its simplicity and the fact that it can be installed without too heavy a cost. That in turn is dependent on the design of the cars and of the whole underground system. For that reason it seems to be necessary to call attention to some features of this subject.

Editor's Note: This article is an abstract of a paper presented at the Automatic Railways conference in London, England, sponsored by the Institution of Mechanical Engineers. It is abstracted herewith through the kind permission of the IME. The authors are O. Kekonius and N. D. Kallberg, of the Stockholm Sparvagar, Stockholm, Sweden.

The underground system includes 6 lines with a combined length of about 35 miles and an average station interval of about 3000 ft. More than half of it is within tunnels. The lines have the following technical characteristics.

Maximum speed	75 km/h, 46 mph
Minimum train headway in absence of restrictive signal aspect	120 sec
Maximum gradient	1:25
with two exceptions, namely	1.24
and	1:20.8
Minimum curve radius	650 ft
Minimum curve radius at stations	1000 ft
Track gauge	4 ft 8½ in
Normal Voltage	650 volts
Maximum acceleration	2.24 mph/sec
Average deceleration	2.24 mph/sec

With the exception of some test cars the rolling stock consists of about 600 motor coaches with the same size and type of equipment for traction, brakes, door operation, etc. Each car has four traction motors for driving and for braking. The current is controlled by electropneumatic contactors. During driving and braking the contactors are governed by a current limit relay. The setting of this relay is influenced by the load in the car in such a way that the acceleration during the progression period is independent of the load. Similarly on about a fourth of the rolling stock the deceleration is practically fully independent of the load. The rest of the cars are to be changed so that all cars will in a year or two have load-sensitive brakes. The traction equipment is designed for multi-unit control of up to eight cars. The master controller has three driving positions of which only one is necessary for normal operation.

The cars are provided with the Westinghouse Air Brake SMEE brake equipment in which the dynamic and pneumatic braking are controlled by a single brake valve handle. There is also provision for handling a train only by pneumatic power in event of the dynamic and electropneumatic brakes not functioning. An emergency pneumatic brake is available at all times by means of the driver's brake valve, the driver's safety device, the passenger emergency brake handles, the timing valve in the cab signal system and so forth.

Fig. 1 shows a very simplified schematic diagram of the brake system. The brake valve handle on the driver's brake valve regulates the pressure in the straight air pipe running through the whole train. This is done by the self-lapping valve and the electric self-lapping unit, which through two multiple-wires, the 'Release' wire and the 'Application' wire, governs a pair of electro-pneumatic valves in each car of the train, one release valve and one application valve.

The pressure in the straight air pipe directly affects the dynamic brake actuator, and thereby the rheostatic control of the brake current. Simultaneously there is also some supplementary air pressure in the brake cylinders.

Tests have shown that the braking of a train will be satisfactorily graduated even though the pressure in the straight air pipe is regulated in two steps only.

The cars are equipped with cab signals and an automatic train control system, which will produce an emergency brake application if a driver—or an automatic pilot—neglects restrictive signals.

The cab signal system is of the continuous type, in which the signals are transmitted to the train by induction from signal currents in the rails. The system gives three aspects, H (free run), M (speed limit: 31 mph) and L (speed limit: 9 mph). Fig. 2 shows when the different aspects are given. This sys-

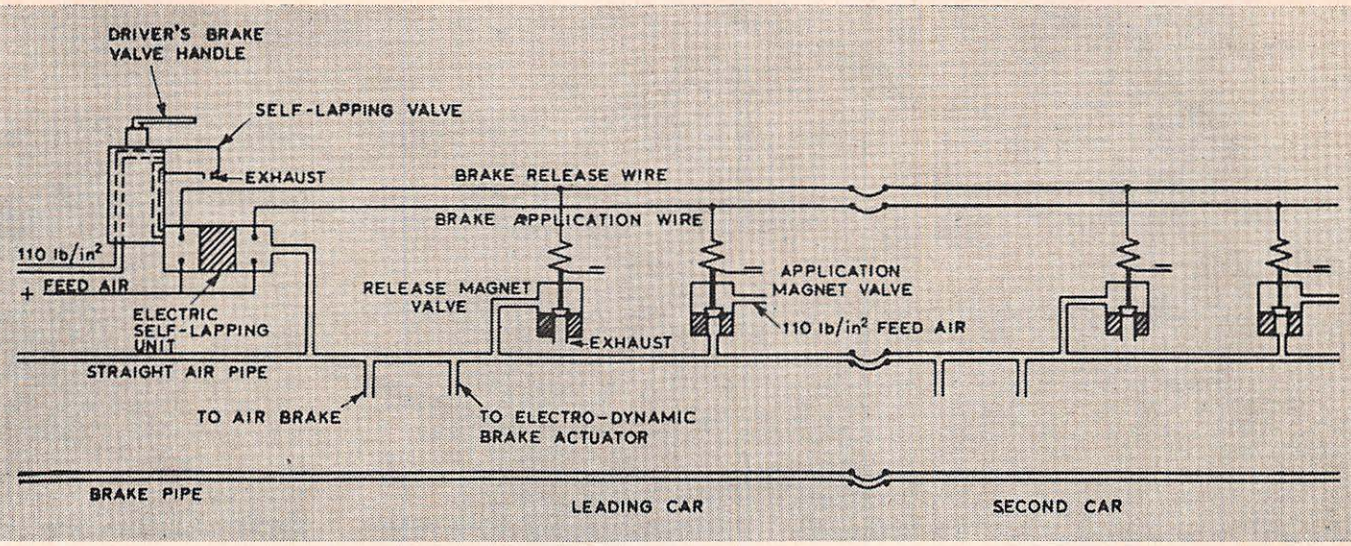


Fig. 1—Schematic diagram of brake system used on Stockholm subway trains having automatic pilot.

tem has been used for 14 years and has proved to be extremely reliable. It means that the safety of the underground system can be based entirely on the cab signal system.

These points can be summed up in this way. It is possible to operate a train simply by controlling some relays in the drivers cab: one for driving/coasting, one for full service braking, and one for half service braking. For special purposes it has been necessary to add another two braking relays, all of which are controlled by impulses from a door signal relay, the cab signal relays of the ordinary car equipment or from the electronic circuits of a computer.

Before the driver can give the train over to the autopilot he has to charge the air brake system as usual and put the handle in the running position. After that he turns a switch from Manual to Automatic and thereby energizes two magnetic valves. One of these cuts off the valve operated by the driver's safety device and the other cuts off the service brake part of the driver's brake valve, that is, the self-lapping valve. The emergency brake part, however, remains unaffected.

Besides these two valves the Automatic-Manual switch connects the Release wire and the Application wire with the brake relays via a brake pressure indicator, which is connected to the straight air pipe running through the whole train. This brake pressure indicator is fitted with a number of contacts, which have to energize and de-energize the Release wire and the Application wire when the desired braking relay controlled pressures

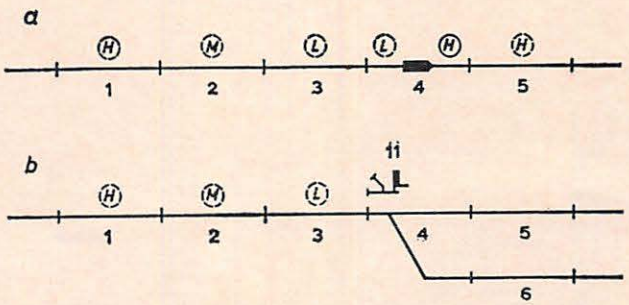


Fig. 2—Three aspects of cab signal equipment. If a train is on track circuit 4, and if signal 11 shows "stop", a following train will receive cab signal aspects H, M and L on track circuits 1, 2 and 3 respectively.

are reached in the straight air pipe. These three details, the two valves and the air brake indicator, are the only additions to the brake system of the cars.

Beside the Automatic-Manual switch and the necessary wiring to the electrical equipment of the cars the following have been added:

(1) A portable computer unit including a receiver for the wayside signals and an electronic computer.

The receivers and the computer are transistorized but the input circuits and the output circuits of the computer are controlled by or control micro relays. The latter simplify the circuits, and at the same time transients from the car equipment are prevented from intervening with the transistorized circuits of the computer. The computer is built up of logical circuit elements of the type now in common use. The elements are mounted on cards. The computer box has the dimensions 7" x 8" x 12" and the weight is about 16 lb.

(2) A relay box with the power relay and the four braking relays mentioned above.

(3) A tachometer generator mounted on one end of a traction motor shaft and intended to give information of actual speed and distance travelled to the computer.

(4) An antenna for the wayside signals.

The wayside equipment consists of two impulse transmitters, each connected to a loop located between the rails and placed at the required distance from the stations. One indicates that the distance to the correct stopping point at the next station is 1070 ft. The other indicates a point where the motor current should be shut off in order to save power.

The transmitters are of a simple type. The power consumption is about 3 watts and the frequencies are about 4 kc and 6 kc, respectively.

Fig. 3 shows the schematic diagram of the automatic pilot. The computer receives information about:

(1) Permitted speed; from the cab signal equipment. The information is given as a voltage on one or two wires.

(2) Actual speed and distance

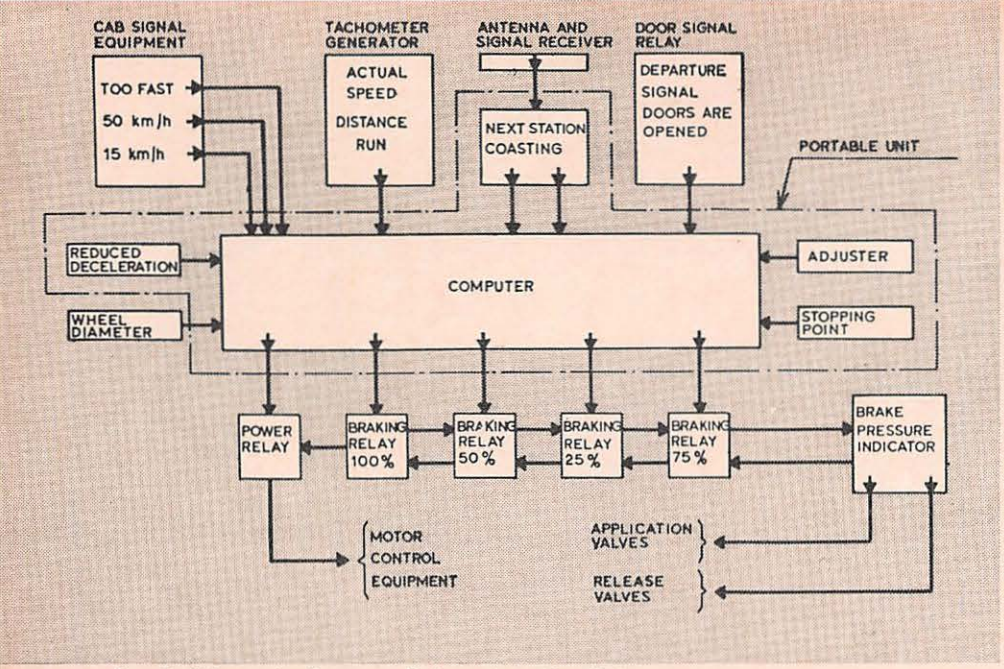


Fig. 3—Schematic diagram of the automatic pilot.

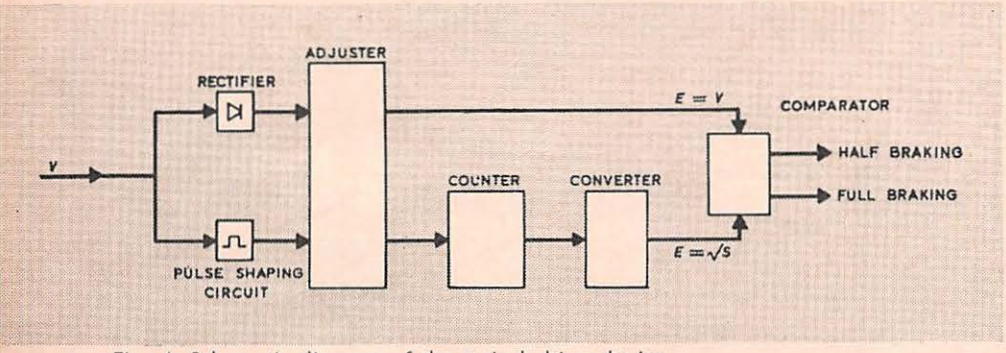


Fig. 4—Schematic diagram of the train halting device.

travelled; from a tachometer generator. The speed is given as a voltage proportional to the speed, and the distance travelled as a number of peaks on the alternating current from the tachometer generator.

(3) Distance to the next station and 'suitable point for coasting', from the wayside equipment. In both cases the information is given as an impulse from the signal receiver.

(4) Given departure signal and about opening of doors. In both cases the information is given as a voltage or as an interrupted voltage on a wire from the door signal system.

On the basis of this information the computer gives the order for power, full-braking and half-braking, and that is all that is necessary for ordinary running. The orders are given by energizing and de-energizing the power relay and the brake relays. Much of this ordering is carried out by simple logical relay circuits.

The method of operation is:

(1) When the guard has closed the doors and given the departure signal, the power relay and the brake relays are energized, which starts the train. Then the train will run until the automatic pilot is influenced by signals from the cab signal system or the wayside impulse transmitters. Apart from the notching time, the acceleration of the train during this period is entirely dependent on the tractive effort of the motors, the track profile and the load of the cars.

(2) If the train—when running faster than 31 mph—gets an M-signal (speed limit 31 mph), the power relay and the brake relays are de-energized, i.e. the train will be braked until the speed is below 31 mph.

(3) If the train for any reason gets the most restrictive signal L (speed limit 9 mph) the train will in the same manner be braked to a stop. Then the driver has to take command.

(4) If a door for any reason is opened during running, the power relay and the brake relays will be de-energized and the train braked to a stop.

Fig. 4 shows, however, how the somewhat more complicated stop at a predetermined point is arranged. When the train is running towards the next station the signal receiver picks up a signal from the wayside equipment 1070 ft before the stopping point. This signal starts the counter, which thereafter subtracts the number of pulses of the tachometer generator from a starting number representing the distance between the wayside transmitter and the desired stopping point. Besides this subtraction the counter divides the remainder in accordance with a pre-programmed pattern, which will provide an approximation of the square root of the remainder. Consequently the counter is at any moment able to generate an output that represents the square root of the distance to the desired stopping point. The counter is designed as a binary-digital device and the output is for that reason converted to a voltage, which represents the desired speed.

This desired speed, given as a voltage, is compared in a comparator with the actual speed given as the voltage of the tachometer generator. If the actual speed is higher than the desired, the comparator will order full service braking by de-energizing the full-braking relay and the half-braking relay. If on the other hand the actual speed is lower than the desired speed, half service braking will be ordered. In this way the computer is able to bring the train to a stop at the desired stopping point by interchanging the two braking forces. Ordinarily there are only a few alternations during braking from 40-45 mph to stop, but the accuracy is good enough for the purpose. The necessary adjustments will be treated later on.

Fig. 5 shows a typical braking performance record. As shown by the speed curve the train is not influenced until the actual speed approaches the desired speed for the first time.

If the cab signal equipment gives the aspect M (31 mph), the voltage of the tachometer generator is compared with a fixed voltage that represents the desired speed and in this case full braking, coasting or power will be ordered on the basis

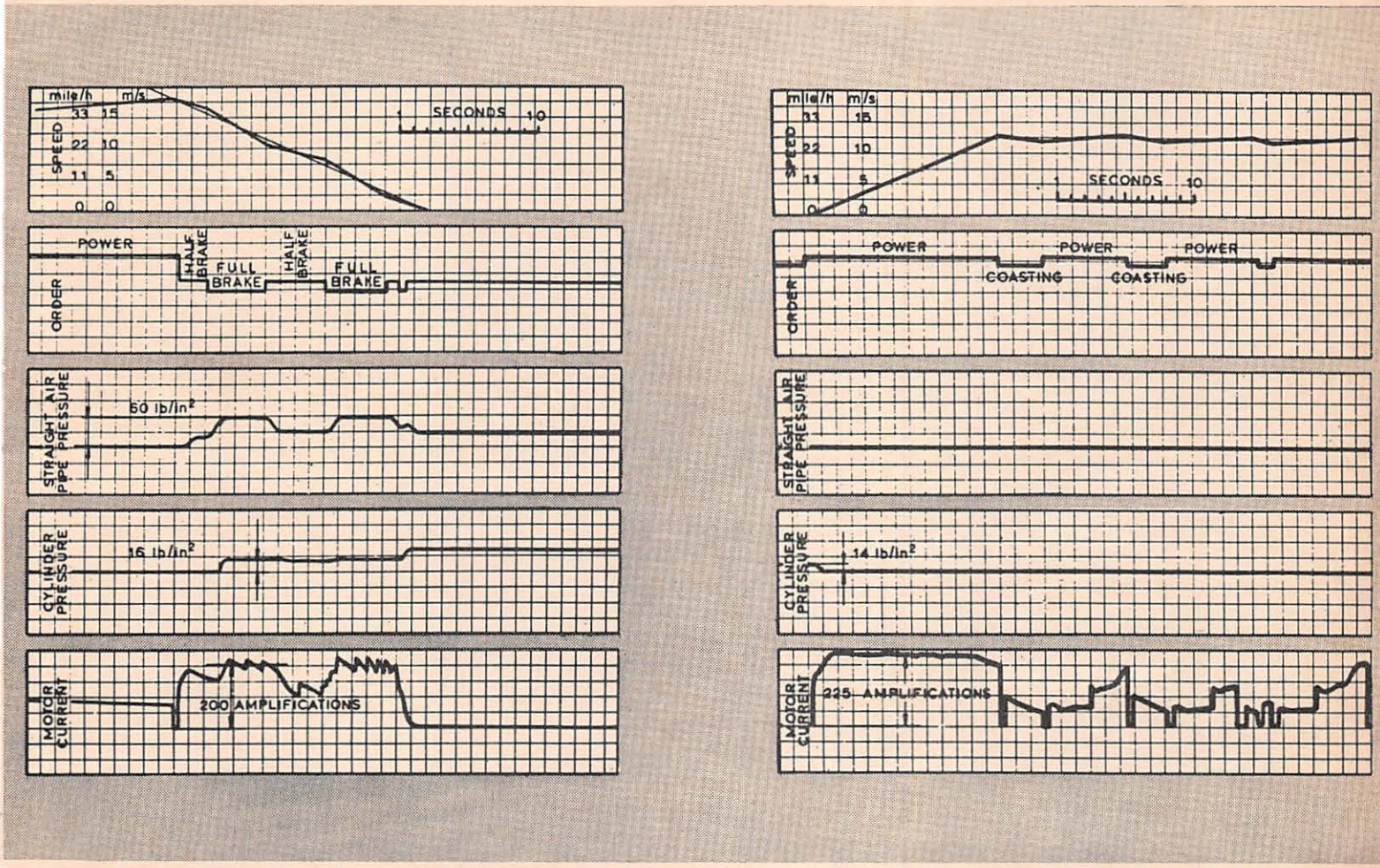


Fig. 5—(left) Braking performance ("order" line—computer to relays.) Fig. 6—Starting and running on basis of M aspect.

of the difference between the actual speed and the desired speed. Fig. 6 shows start and running, when the M-signal is given.

Fig. 7 represents some typical runs when the train is influenced by restrictive cab signals, the coasting signal, etc.

The safety of operation with this automatic train is based upon the cab signal equipment which has already proved to be reliable in the highest degree. For that reason no alterations have been made in the vital parts of the cab signal equipment. There are only connections to the signal lamp L and M and also to a buzzer, which normally indicates when the speed exceeds that permitted by the cab signal. It means that electrical or mechanical failures of the automatic pilot device have no influence whatsoever upon the cab signal equipment.

Concerning unexpected obstacles which may appear on the tracks, it is to be remembered that there is always an operator in the driver's cab who can supervise the track and be ready for action if necessary. He can take command at any moment by turning the Automatic-Manual switch, or by making an emergency brake application.

This, however, touches a problem that as yet has no final solution. As the operator normally is quite inactive during running between two stations, the question arises whether it will be necessary to fit a special device of some kind in order to keep him alert.

SERVICE BRAKING

In an ordinary train, as in the automatic train, the service brake is governed by the two train wires, the Application wire and the Release wire mentioned above. This means, for instance, that a failure in the car coupler may interfere with the braking force. For this reason there is a paragraph in the driver's instructions ordering him to apply the emergency brake, if he observes any weakness in the service braking force. To meet the requirements of this paragraph there is an alteration in the wiring of the automatic emergency brake application if the pressure in the straight air pipe for any reason is lower in the rear end than in the front end of the train. This means that the pressure in the straight air pipe is accepted as a criterion of the braking force, which seems to be justifiable in view of the proved reliability of the brake equipment.

It should be mentioned that the cab signal equipment will apply the emergency brake if the pressure in the straight air pipe in the front end is not increased rapidly enough when the aspect changes and the train is running faster than permitted by the cab signal.

In two-manned trains the guard is placed in the center of the train in order to facilitate his supervision of boarding and alighting passengers. In one-manned trains, however, the operator is to be located in the front cab and at some stations, particularly those with curved platforms and also where there are large

numbers of passengers, his opportunity for supervision will be limited. This has necessitated the installation of industrial television at some platforms.

The ability of the operator to establish contact with the central control office, too, should be mentioned as a question of safety, and one which has increased the demand for radio communication. The technical difficulties with radio communications in tunnels are solved by installing a special feeder cable: a final decision on the radio installation is in sight. A portable train radio unit is contemplated and this has to be considered in relation to the portable computer box as the aim is to decrease the number and weight of the details which the operator has to carry with him to and from his trains.

The length of an 8-car train is 475 ft, the length of a platform is 495 ft. This means that the accuracy shall be within ±10 ft. These 10 ft represent less than one per cent of the braking distance and for this reason the method of distance measurement chosen has been judged to be very critical. The tests, however, have proved that the method will meet the demand in almost all weather conditions.

It is, however, known that on one or two days a year in Stockholm there might be weather with a special type of snow during which the human drivers have to drive with more than normal caution in order to be able to stop at the right point. Owing to this the computer box is fitted with a special switch by which the desired deceleration rate can be lowered from 2.24 to 1.67 mph/sec. This switch has to be used by the operator, if he observes any tendency to overrunning attributable to the weather conditions. As to the risk of skidding, i.e. that the value of the coefficient of adhesion may decrease from 0.15 to about 0.11, the test runs indicate that the lower value is the minimum to be expected.

REDUCE DECELERATION

This reduction of the desired deceleration is effected by a suitable decrease in the voltage from the tachometer generator, which thus gives fictive information of the actual speed to the comparator. Furthermore, the full-braking relay is replaced by one provided specially for the purpose termed the '75 per cent braking relay', which limits the maximum pressure in the straight air pipe and consequently the maximum brake cylinder pressure.

Another thing that is necessary to have in order to maintain accuracy is a compensator for variations in wheel diameter. This is a device which simultaneously makes a suitable reduction in the tachometer generator voltage and a corresponding reduction in the number of pulses from the tachometer generator fed to the counter. This reduction in the number of pulses is made by a special counter which, depending on the position of the adjuster knob, electrically suppresses every tenth or every ninth pulse, etc. Thus compensation is entirely numerical.

On the test equipment the knob is located on the computer box, but as this is to be portable and the wheel diameter compensation should be associated with each car, a part of the adjusting device is to be fitted on the cars themselves.

Besides the wheel diameter com-

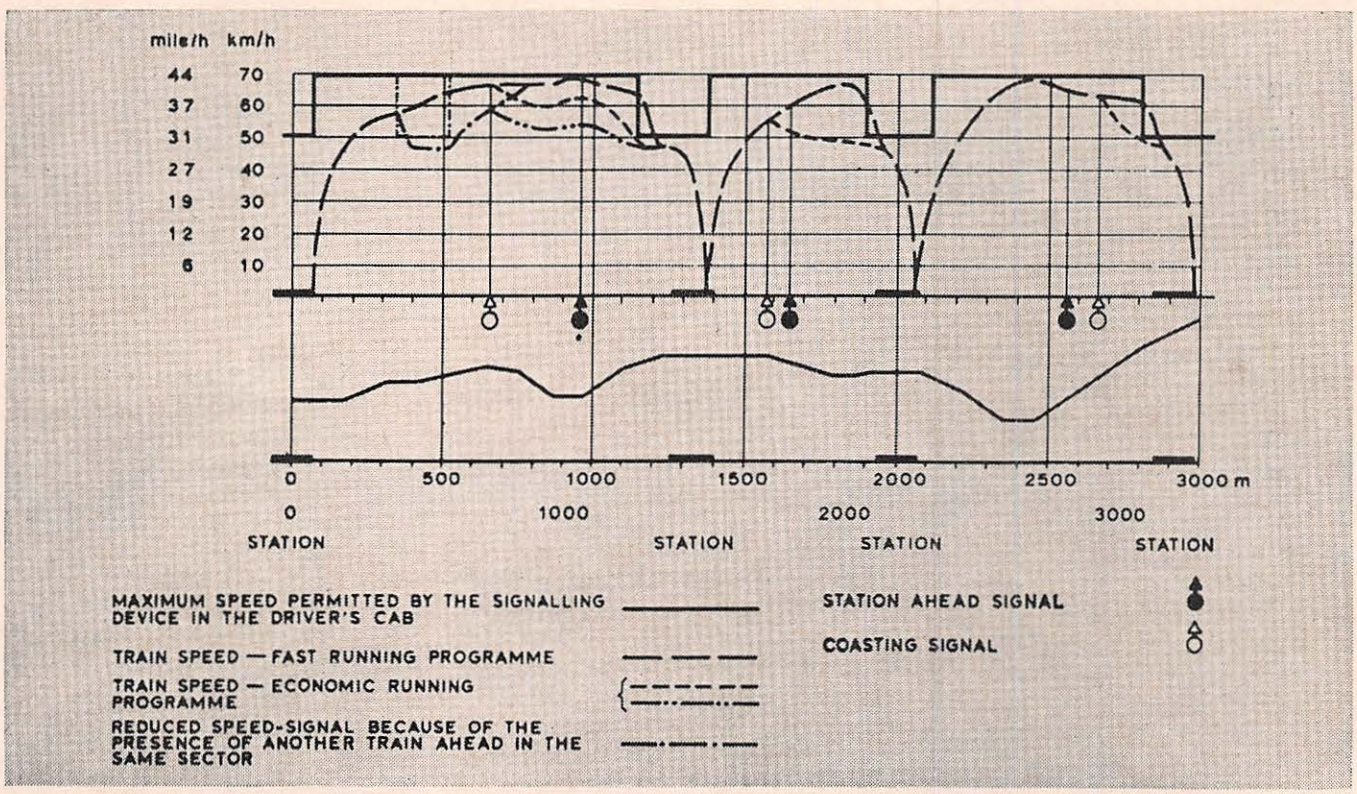

mile/h km/h
44 70
37 60
31 50
27 40
19 30
12 20
6 10
0 500 1000 1500 2000 2500 3000 m
0 1000 2000 3000
STATION STATION STATION STATION
MAXIMUM SPEED PERMITTED BY THE SIGNALLING DEVICE IN THE DRIVER'S CAB
TRAIN SPEED — FAST RUNNING PROGRAMME
TRAIN SPEED — ECONOMIC RUNNING PROGRAMME
REDUCED SPEED-SIGNAL BECAUSE OF THE PRESENCE OF ANOTHER TRAIN AHEAD IN THE SAME SECTOR
STATION AHEAD SIGNAL
COASTING SIGNAL

Fig. 7—Typical runs when train is influenced by restrictive cab signals, coasting signal, etc.

control on account of weather conditions.

pensator a 'normal' control, with a corresponding method of working has also been fitted. Its task is to enable the operator, if necessary, to select a better stopping point.

As the calculation of the desired speed in the computer, apart from the converter, is made numerically and the voltage of the tachometer generator is controlled by the wheel diameter compensator, it seems possible that this additional adjustment is superfluous, but it has been included for the sake of safety.

It should also be mentioned that the computer box is fitted with a special control by means of which the operator in the case of shorter trains can select a more suitable stopping point than that at the end of the platform. The method of changing the stopping point is to lower the initial figure at which the counter starts to calculate the desired speed, when the station ahead signal is received.

Passengers' comfort may be regarded as presenting two different problems. On one hand the method of driving with the train running at maximum speed may produce disagreeable accelerations for the passengers owing to curves or track irregularities; on the other the method of braking by interchanging half- and full-braking may be too rough.

As to the question of high speed it should be mentioned that the track system is built to permit this and that the cab signal equipment will always give restrictive signals where curves and gradients prohibit maximum speed.

It should be mentioned that if no restrictive signals occur the human drivers, too, at least during rush-hours, drive as fast as the tractive effort permits. Test runs on a great part of the lines have proved that there are scarcely any difficulties produced by the transverse accelerations of the cars. In spite of this fact a third signal receiver is fitted in the computer box as a reserve, should there be some points in the system where a speed reduction may be necessary. In that case the third receiver will pick up a signal from a special wayside transmitter suitably placed, which will order coasting and reduce speed.

As regards changes in deceleration during braking the fact is that the time constant of the brake system of the cars is so great that the brake application will always be comparatively smooth. Fig. 5 illustrates these points. As the normal brake application before a station—owing to the computer's method of working—always starts with half-braking, the time for changing from acceleration to full deceleration amounts to 3.5 sec. This produces a rate of change in acceleration of 1.3 mph/sec^2, which is tolerable.

The changeover from full-braking to half-braking or the reverse gives about the same value.

If an unexpected restrictive signal occurs this may result in a change of acceleration of 2.2-1.5 mph/sec^2 independently of whether the train is driven by a human driver or not. Presumably the automatic pilot will brake somewhat more smoothly than the driver owing to the fact that the automatic pilot always does things in the proper sequence. In addition to this some small differences in the valve ports may promote smoother braking.

END OF BRAKING

The most critical point, however, is at the end of braking, when the brake current fades and the brake cylinder pressure increases. See Fig. 5.

In order to make a brake stop end smoothly the human drivers have to ease the brake pressure at the moment of stopping and similarly the logical circuits of the computer are so arranged that half-braking is always ordered when the speed of the train has been reduced to about 4 mph, i.e. when 1-2 sec of braking time still remains. This, however, may be a time too short to permit the desired release, which means a disagreeable jerk. For this reason several methods of softening this jerk have been discussed, but as every method involves a decrease in accuracy, they must be studied and thoroughly tested. Owing to this no decision on this question has yet been reached.

For the sake of completeness it should be mentioned that the brake pressure is released to about a quarter of its value at the moment when the train has stopped and the doors have been opened. This is effected by a special relay the '25% braking relay', which is energized when the doors are opened. The purpose of the arrangement is to get a brake force great enough to hold the train stationary, but rapidly releasable at the start.

Investigations proved that an appreciable saving in power consumption can be made by a slight increase in running time. A noteworthy example of this is the section between the Slussen and Gamla Stan stations, where an increase of running time from 50 to 58 sec reduces the power consumption by 40%.

As the capacity of the underground system must be utilized to the fullest extent in rush-hours, the necessity for two different programs is evident.

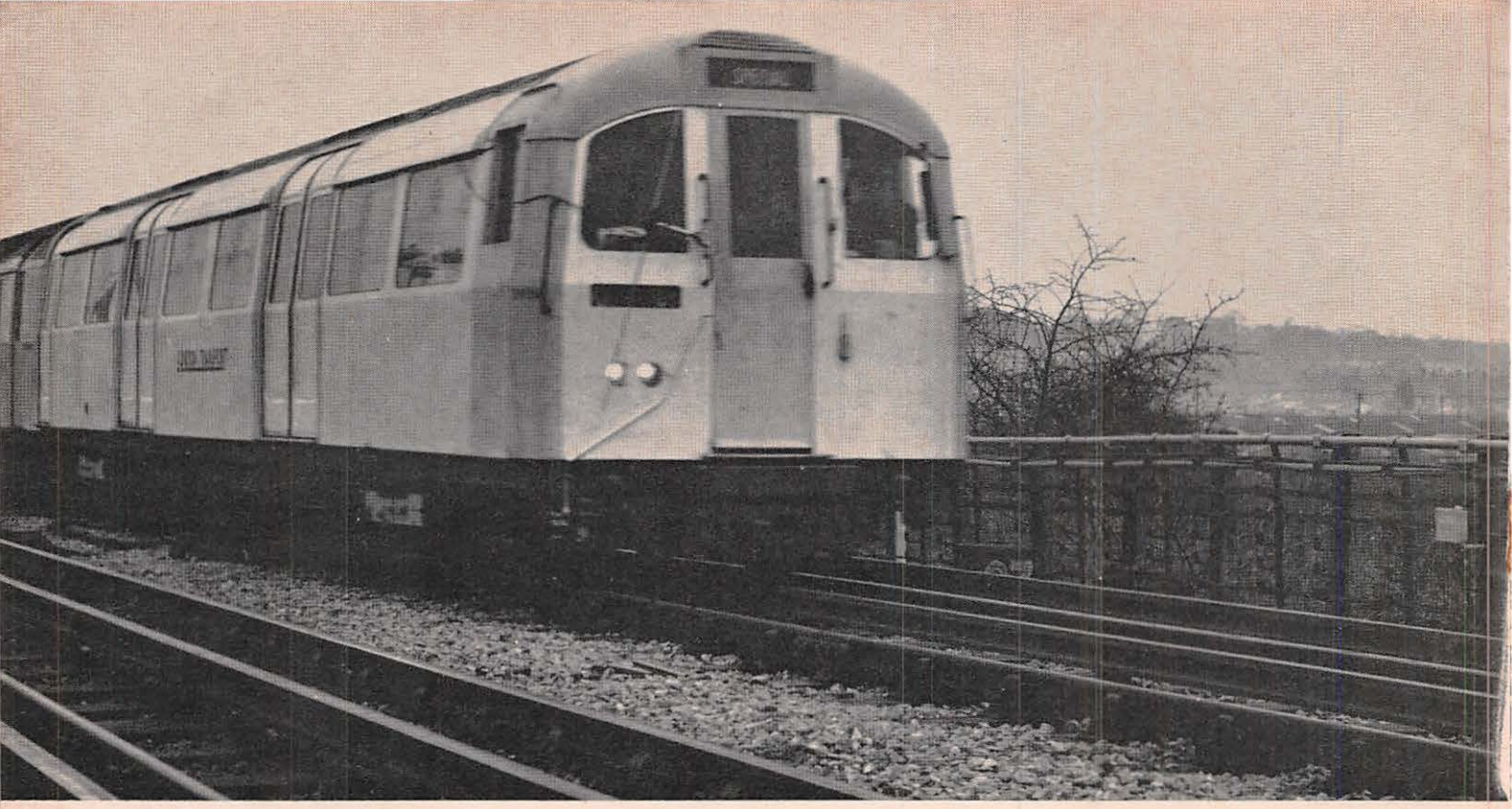
On the test equipment the choice of program is made by a switch on the computer box, but for the future there is the possibility of removing the choice from the operator to the central control office.

The correct location of the transmitter loop is of decisive importance in attaining the desired saving in power consumption. For this reason the location of the loops is to be calculated with the aid of computing machines.

The first prototype of the automatic pilot was demonstrated in September 1962 and regular test runs started in January 1963. The line prepared for automatic operation included seven stations and after a year about 10,000 test runs had been made. The test runs have been successful, but have, of course, led to some improvements in the equipment. Thus the '75% braking relay' and the '25% braking relay' have been fitted, some weak points in the car equipment have been discovered and removed, and so on.

The test train has been made up of varying numbers of different types of cars. Up to February 1964, however, only one car had been prepared as a leading car, but in March

(Please turn to page 42)



Train equipped for automatic operation is approaching a "co mmand spot" (wayside equipment at right) on a test run between

AUTOMATIC TRAIN OPERATION—III

London Transport has ATO in

THE ADVANTAGES to be achieved by automatic train operation may be summarized as follows:

(1) Regularity of service, deriving from uniformity of driving technique.

(2) Reduction in minimum headway achievable—and, therefore, an increase in the maximum line capacity.

(3) Maintenance of timetabled performance within minimum possible energy consumption.

(4) Enforced observance of speed restrictions.

(5) The ability to provide for automatic recovery from service delays.

(6) The possibility of reducing operating manpower.

It is true that in many respects the automatic control can do no better than a good human driver: indeed it is sometimes alleged that a good human driver can, in some respects at least, exceed the performance of the automatic controls. Experience shows, however, that on average the superlatively good human driver is likely to be followed by one of less than average ability and the net effect of the first man's superior driving is to widen the gap between the two trains to an extent which reacts to the increasing detriment of the following train. With automatic operation, not only is the running performance of the trains maintained to a consistent level, but, if due to abnormal influences a station stop is prolonged, means can automatically be invoked in an endeavour to recover the lost time and, what is perhaps even more important, on a system such as the London Underground, to regularize the service interval.

With any scheme of automatic train operation the question is bound to arise at an early stage in considerations—how are the instructions to be conveyed to the train? This problem resolves itself most usually by the recognition that a program has to be devised for the train operation, and that the alternatives available are:

(1) A program carried on the train, or

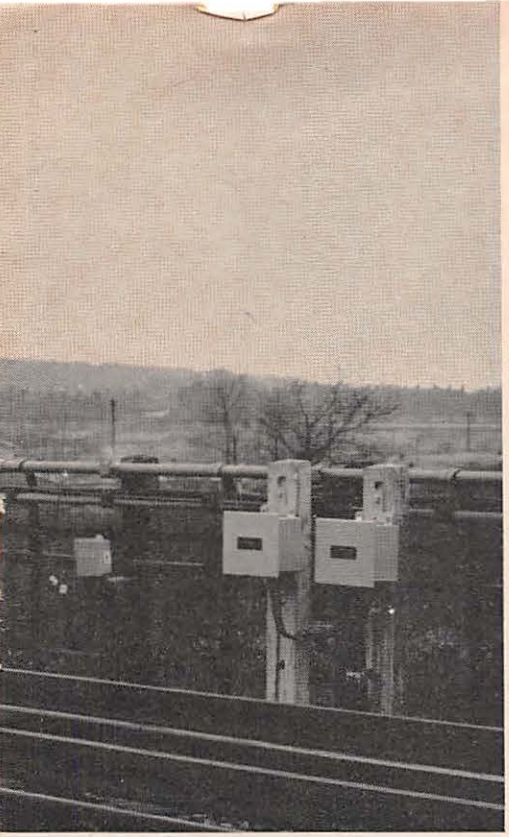
(2) A program indicated on the track.

Because of the fact that the London Transport services are, in the main, of an exactly repeating character it was thought originally that it would be most appropriate to put the program on the track and to equip the trains with apparatus which responded always in the same general way to the same indication transmitted from the track.

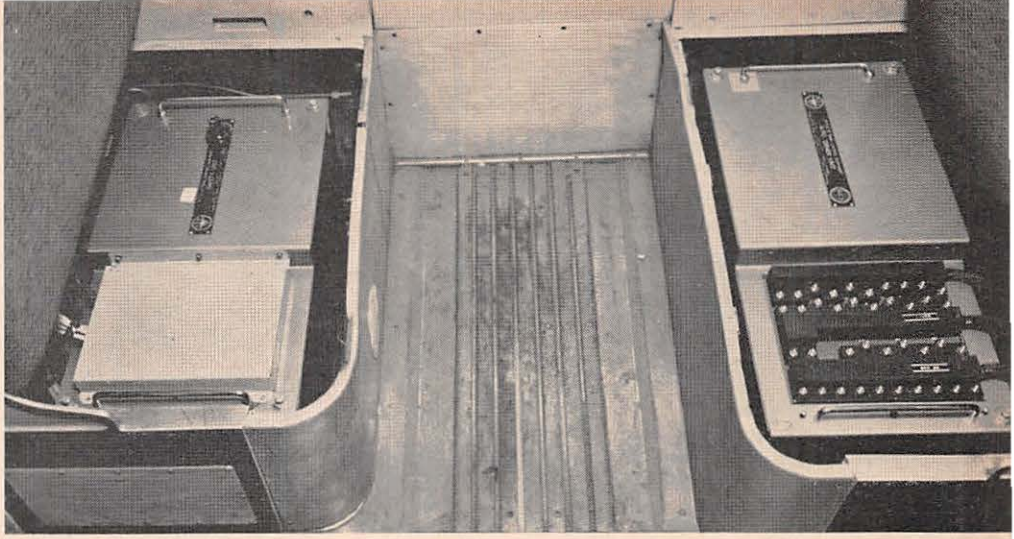
Although viewed originally as a scheme peculiarly suited to the London Transport requirements the experience in operation has shown the scheme to be flexible that its advantages for other types of service are considered to be manifest.

With the program on train concept there is always found the need to provide calibrating indications from the track, and there is ever

Editor's Note: This article is an abstract of a paper presented at the Automatic Railways conference in London, England, sponsored by the Institution of Mechanical Engineers. It is abstracted herewith through the kind permission of the IME. The authors are R. Dell, chief signal engineer, and A. W. Manser, chief mechanical engineer, London Transport Executive.



Hainault and Woodford.



Safety signaling code equipment (left) and "automatic driver" on train.

service

present the problem that if the train is diverted from its timetabled route (or reversed in direction) someone must adjust the program device to take acount of what has happened. With the program on track, as described in what follows, no difficulty arises in the event of unscheduled working: the program is there ready for any train which comes along. Even with trains of varying performance all that is necessary is to provide separate indications to insure advance action in the case of stock which may be fitted with less than normally efficient braking.

Experiments and trials with automatic driving of electric trains have been in progress on London Transport since 1962. The work is now in its third stage, the first stage comprising laboratory tests of equipment and development of circuits, and then the production of one trial train which was run in passenger service for one year from April 1963 until April 1964. In April 1964 the present extended trials of automatic train working on the Hainault Loop were commenced. This installation comprises a section of double line having five stations and the service is entirely run by automatically driven trains in passenger operation. It is intended that there should be one attendant on the train and the design of the equipment has been arranged accordingly. The attendant opens and closes the passenger doors at stations and after closing the doors presses the starting buttons. Two buttons are provided to guard against inadvertent operation. After that the whole operation of the driving of the train is carried out automatically—the train starts from the station, stops if signals are at danger, restarts when signals clear and stops at the next station.

The automatic driving equipment is arranged to take advantage of the characteristics of the train, and no upper limit is imposed on the speed of the driving equipment. When the train is running under clear signals the speed is determined only by the natural characteristics of tractive effort and train resistance. The train is, however, provided with equipment enabling the speed to be controlled at 22 mph for use when trains are being brought close together with minimum headway and when a lower speed than the maximum is required on certain parts of the line by reason of track layout or condition. In addition to this, the automatic driving equipment provides a considerable measure of flexibility so that even lower speeds can be insured if required, for example, when passing through crossovers and junctions.

Subsequent to the one act by the train attendant (the pushing of the start buttons), the automatic driving is effected by signals conveyed from the track to the train by induction. The whole of these signals are conveyed through the running rails and picked up by coils mounted on the front of the train. A dual system is employed: the automatic driving commands, which are intermittent and are arranged to control all the normal driving conditions of the train, and in addition to this, a safety signalling system which is in the form of continuous coded signals which are also picked up from the running rails.

The automatic driving commands are in the form of signals in the range of audio frequency between 1 and 20 kc. Currents at these frequencies are passed through sections of running rail about 10 ft long, called spots, and these are positioned at points on the track where it is required to give a driving command. These commands are divided into two groups; one group is used for the application of the brakes for stopping at a station. One particular frequency, 15 kc, is used to cause the motors to switch off and another frequency, 20 kc, is used to apply the brakes when there is a signal at danger ahead. The audio frequencies employed for the stopping at stations are so arranged that 100 cycles represents 1 mph. In this way a command which can be interpreted as 30 mph is 3 kc and 20 mph is 2 kc. The audio frequencies for the braking command spots are applied in bursts of 127 cycles, followed by a pause of a similar duration and then a repeat burst of 127 cycles and so on. This is done for two reasons, (1) the use of 127 cycles allows a nu-

merical form of comparator to be employed on the train and, therefore, achieves a very high degree of accuracy, and (2) it insures that the train recognizes only genuine signals which must comprise 127 cycles, no more and no less. The 15 kc coasting spot and the 20 kc signal stop spot are not gated in this fashion as the frequencies are above the range in which interference is ordinarily encountered and the accuracy of counting is not required; these signals are recognized by tuned circuits. Fig. 1 shows the arrangement of the electrical circuits for a command spot for station braking. The audio frequency is generated by a transistor oscillator which is adjusted to the frequency required to indicate the braking speed. The output from the oscillator is counted by a binary counter which operates a gate feeding the power amplifier. The binary counter with the gate open counts 127 cycles and then closes the gate for the next 127 cycles. The output from the power amplifier which produces a minimum of 5 va is then fed direct to the rail through a step-down transformer.

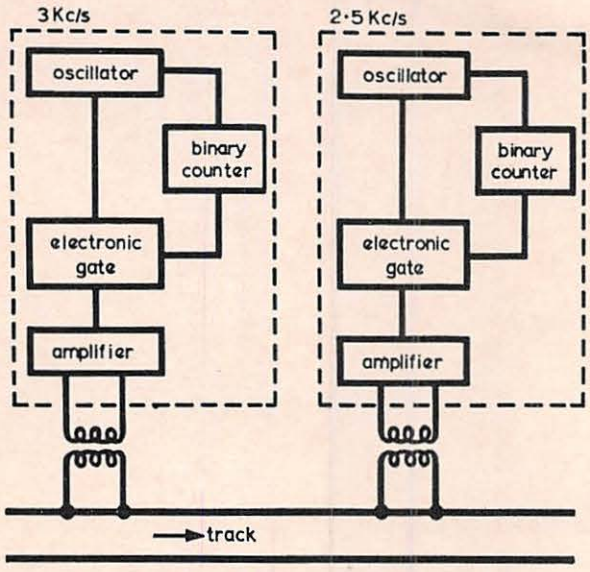


Fig. 1—Arrangement of electrical circuits for a command spot for station braking.

The train braking equipment is arranged, for automatic working, to give as required any one of three rates of retardation, maximum, normal and minimum. The speed at which the train can be expected to approach the station is calculated and the distance at which the brakes must be applied from the stopping point is also calculated for normal braking, and at this point a command spot is fitted on the track set for the calculated speed (on the basis already mentioned of 100 cycles being equal to 1 mph). The calculated speed-distance curve for the train from this point to the stoping point is plotted and the points at which successively lower speeds should be attained are ascertained from this calculation and successive command spots are fixed on the track, generally at speeds descending by 5 mph. The arrangement for this braking is shown in Fig. 2. As the train approaches the station it receives the first braking command and if the speed of the train is in accordance with the calculated value a normal brake application will be made. If the train at this point is running at a higher speed than the calculated value, then a maximum brake application will be made. Similarly, if the train is running at lower than the calculated speed a minimum brake application will be made. Provision is also made that if the speed of the train is more than 20% less than the command speed, a brake release is made if the brakes are on. The train having commenced to brake, soon reaches the next calculated spot where a fresh speed indication is given. A further check is made of the speed and if the speed is at the calculated value the brake application remains at normal. If, on the other hand, the train is going too fast the brake application is increased or decreased if it is going too slow. This process is repeated at each of the braking command spots until the train is brought to rest at the required position in the station. A circuit is incorporated in the train equipment which, when the speed has been reduced to 4 mph, causes the brakes to be partially released so that a gentle stop is made at the end of the braking run.

The command receiving equipment on the train is shown in the diagram Fig. 3. Signals from the rails are picked up by the coils on the front of the train and amplified by a transistor amplifier fed from the train battery. The train is equipped with a tachometer generator, the output frequency of which is on the basis of 100 cycles equals 1 mph; this frequency can, therefore, be compared directly with the command signals received from the track. The comparison of command speeds and actual speeds of the train is carried out digitally. After amplification the signal picked up by the train from the track is fed into one of two binary counters arranged to count 127 cycles. A second binary counter is switched in by the first signal received from the track, but is actually driven by the frequency from the tachometer generator and counts this frequency. The two counters, therefore, run at the same time, having started together; the track counter counts 127 and then causes both counters to stop. The number of cycles which have been counted by the tachometer generator counter then indicates whether the speed of the train is greater or less than the command which has been received, and a braking signal is given as an output from the point at which the train speed binary counter has stopped. If the command binary counter does not count exactly 127 then both counters are returned to zero and the signal disregarded as being a spurious one. It should be noted that this form of digital comparison gives a high degree of accuracy because even allowing for one cycle error in the pick-up of the tachometer signals this gives a maximum error of less than 1%. The output of the binary counters is arranged to actuate one of three relays and these in association with mercury tube retardation controllers insure that the required rate of braking is achieved and thereafter maintained

by energizing or de-energizing as appropriate the various electro-pneumatic valves controlling the feed of air to the brake cylinders. The automatic driving command system, although arranged to operate with a high degree of reliability, because of its intermittent nature cannot be regarded as a fully fail safe system. Therefore, a second signalling system, providing the fail safe feature, is employed to insure the correct working of the train.

The safety signalling system is a continuous one based on coded track circuits. The coded track circuit current is fed through one rail of each track circuit, flows through the axles of the train and returns by the other rail of the track circuit. A coded signal must always be picked up by the second set of coils mounted on the front of the train to permit the train to proceed and should the coded signal not be received or be of a different value than that required by the train speed at the time, an emergency brake application is made and the train brought to rest. This emergency brake application stops the train and the circuit requires to be reset by special reset buttons by the train attendant before the train can restart.

The coded track circuits are operated at a special frequency of 125 cycles. This is a frequency which is different from any mains frequency or any harmonic of mains frequencies and, therefore, is likely to be free from any interference. The codes employed are given in the following table:

120 pulses/min for operation of fixed signalling equipment only.

180 pulses/min permits the train to run at a speed not exceeding 25 mph without application of motors.

270 pulses/min permits the train to operate at a speed not exceeding 25 mph and arranges for the motors to be switched on if they have been switched off previously by a coasting or braking command.

420 pulses/min permits unrestricted running within the capability of the traction equipment.

The 270 code brings into operation a control of the train equipment regulating the speed at a nominal 22 mph.

Fig. 4 shows diagrammatically the arrangement of a coded track circuit and also the pick-up coils of the

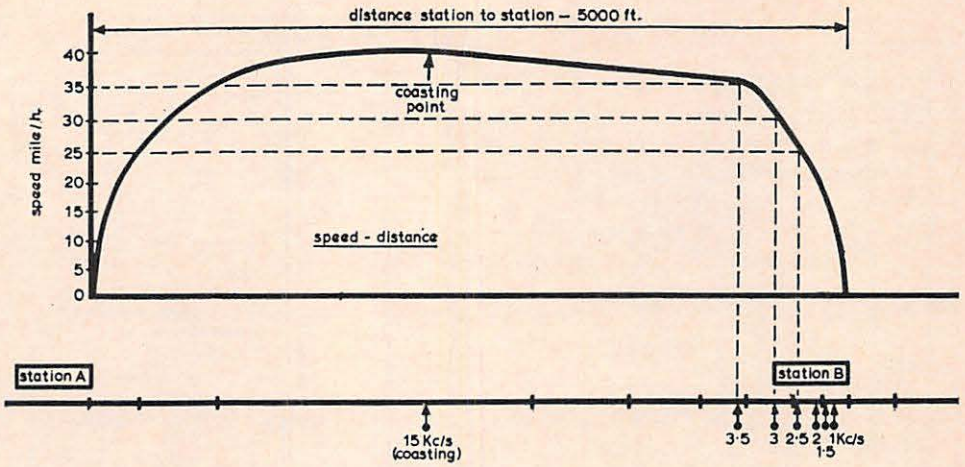


Fig. 2—Braking sequence as a train approaches a station.

safety signalling circuits on the train for making an emergency brake application. The 125 cps current from the mains supply is fed through a transformer to step it down to a suitable voltage for the transistor gate and then through a second transformer which steps it up to a sufficiently high voltage to feed the current through a series capacitor to the track rails. The current through the track circuit rails is arranged to be not less than 4 amp so as to give an adequate pick-up to the train. At the relay end of the track circuit is a track receiver for detecting that code is being superimposed on the track circuit current and the output from this track receiver operates a DC track relay. The train shunt value of this form of track circuit is not less than 1 ohm. The electronic gate used for superimposing the codes on the track circuit current comprises transistors bridged across a bridge rectifier, the rectifier enabling the transistors to operate on the DC side although effectively switching the AC. Pulses of DC are generated by code generators and these are switched on to the electronic gate by relays having their coils in circuits detecting the clearing of track circuits ahead so that the appropriate frequency of code is applied to the track circuit according to the state of the track ahead. When there is a train on the track immediately ahead of the track circuit under consideration, code at the rate of 120 codes per minute is applied to the track circuit. This code is not received by the train equipment at all, but is used only for actuating the track relay and hence for detecting the presence of a train on the track circuit. As the

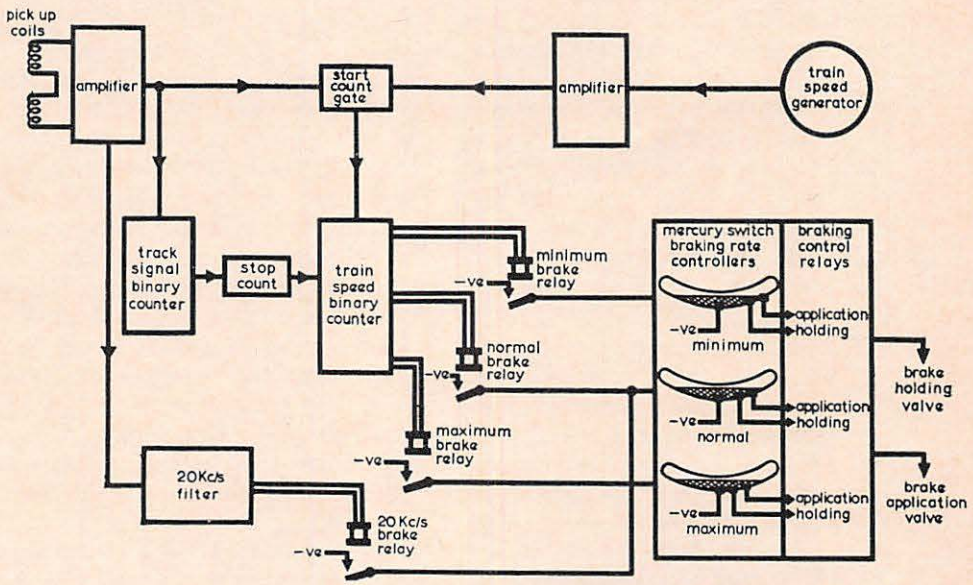


Fig. 3—Schematic diagram of command receiving equipment.

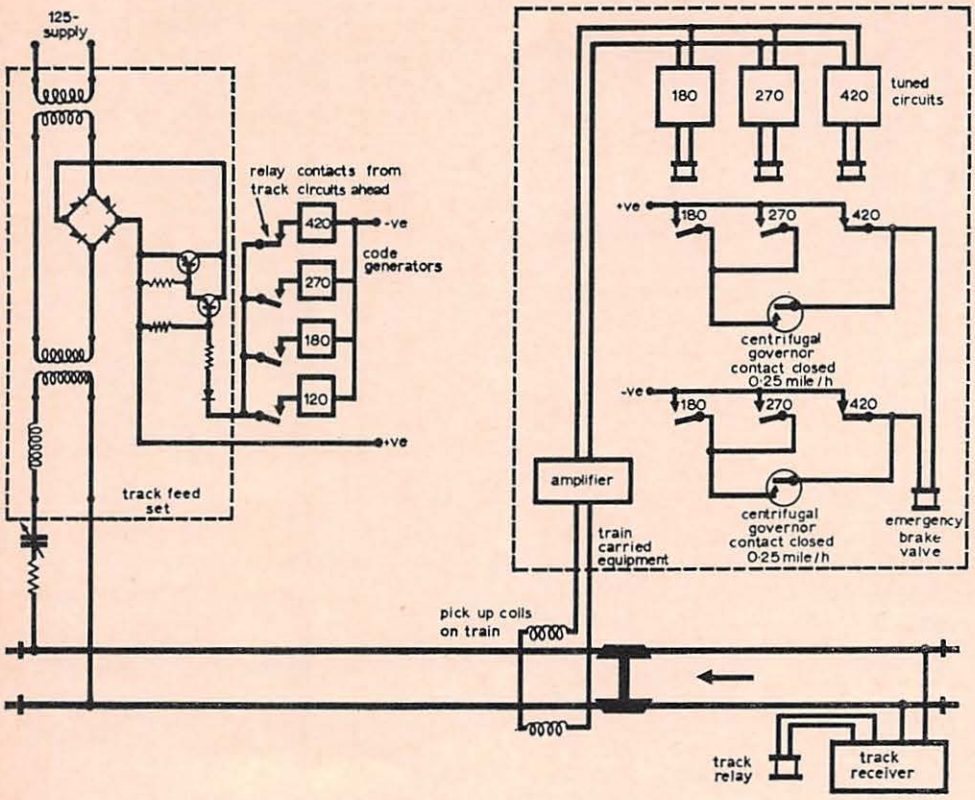


Fig. 4—Plan of coded track circuit and pick-up coils of safety signaling circuit.

track circuits applying to the track ahead become clear the codes are successively raised to 180 per minute, 270 per minute or 420 per minute, switched by the track relay contacts shown. The coded impulses are received by induction in the pick-up coils on the train and the 125 cycle basic frequency is recognized by a tuned circuit. The signals so received are amplified by a transistor amplifier, the output of this amplifier being fed into three tuned circuits each tuned to respond only to one of the code frequencies. The output of these tuned circuits is then used to actuate DC relays, the contacts of which maintain a continuous circuit to hold the emergency brake valve in the energized position. Failure of the supply of current from any of these code relay circuits to the emergency brake valve will result in this valve being released and a brake application made.

The code generators for producing the codes to be applied to the track circuits are arranged to have high degree of accuracy and to be fail safe in the condition that no fault of the equipment shall cause it to give a higher frequency code than that for which it is designed. To insure that this condition is retained, the code generators for all the code frequencies, except 420 code, employ a tuned pendulum to generate the code frequency. The balance weight on the pendulum is formed of permanent magnets which react with two fixed coils; one coil is used to maintain the oscillation of the pendulum and the second coil to actuate the output circuits. The whole of the circuitry for maintaining the oscillation of the pendulum and for producing the output code is electronic, employing transistors, and no physical contacts are provided with the pendulum which swings entirely freely. This form of construction of the code generator is a complete assurance against the generator accidentally giving a higher code than that for which it is designed. For example, if the spring supporting the pendulum became cracked or weakened this would have the effect of slowing down the pendulum and giving a slower code. Also, because the weight is in the form of the permanent magnets which cause the pendulum to operate, if the weight were to become detached, the operation would then stop. Where track circuits are spread out individually along the line, separate code generators are provided for operating each track circuit, but where a number of track circuits are grouped together, especially in interlocking areas, then a signal code generator for each frequency is arranged to supply a power amplifier which in turn feeds code bus bars which are used to provide code for a number of track circuits. This is an advantage especially in interlocking areas as all track circuits then operate in synchronism and tests at insulated joints are made more easy and there is less disturbance of the received signal on the train when passing over the insulated joints. Special care has to be taken at insulated joints to maintain a continuous signal right up to the joint for the train receiver. It is the normal practice to connect cables a few feet back from the end of the rail and to maintain the continuous induction these cables are laid close to the rail parallel with it to the actual point of the insulation so that there is no break in the magnetic field at this point.

The automatic control of motoring presented no great problem. All modern London Transport stock has automatic acceleration control, the dropping out of a current relay permitting successive notching round of a pneumatically operated camshaft which cuts out the motor series starting resistances. Transition from series to parallel connection of the motors and a first stage of field weakening are controlled by the same relay, and a second stage of field weakening by another relay with a lower current setting. Two settings of the accelerating or notching relay can be selected and thus two rates of acceleration can be obtained.

TUBE STOCK TRAINS

The 1960 tube stock trains which are being used in the automatic train operation trials have 4 motors per motor car, the two in each truck being permanently connected in series. With this arrangement it has been thought desirable to limit the acceleration to a value corresponding to 15% adhesion (with 600 volt motors 20% is the nominal figure) which gives a rate of roughly 1.5 mph/sec. Wheelspin relays are provided which open the main line-breakers and thus return the camshaft to the starting position if a differential between the back e.m.f.'s of two series motors is detected. These two features have assisted the

application of automatic train operation to this particular stock in that it has been possible to use the higher acceleration rate of the notching relay without causing any appreciable wheelspin trouble in wet weather.

For safety twin pushbuttons are used to start the trains from a station, energizing independent circuits which feed the two train wires needed to initiate motoring. Two other wires selecting parallel connection of motors and weak field are also energized under 420 code conditions. At a signal stop only one of the holding circuits is cancelled so that the application of 270 code can restart the train without action by the train operator, see Fig. 5.

The starting buttons circuits are arranged so that the train can only be started from a station when 420 code is being received, the train is stationary and the passenger doors and cab sidelights are closed.

NORMAL SERVICE BRAKE

The normal service brake on London Transport stock is electro-pneumatic, controlled by application and holding valves on each car. Blowdown valves are also provided which release air if the maximum rate of braking permitted by adhesion is reached. This rate is detected by a mercury switch, and it was a simple matter to provide further mercury switches to control the three rates of braking selected by the binary counters. Each rate is obtained by cutting off the feed to the application train wire at a retardation slightly below the nominal value, and cutting off the feed to the holding train wire if some rate slightly above the nominal value is reached. The three rates as applied to the Hainault-Woodford trains are approximately 1.5, 2.1 and 2.6 mph/sec.

When the speed falls to 4 mph control of brake cylinder pressure is transferred from the mercury switches to pressure switches, partially easing the brake to avoid a jerk on stopping, and providing sufficient pressure to hold the train against any gradient which may exist.

The tachometer generator used to provide the frequency which is compared with the braking command spot frequencies is mounted on the end of a traction motor. It employs two toothed wheels, one having 144 and the other 150 teeth each with a pick-up head, either of which can be selected to permit some degree of compensation for wheel wear.

This generator is also used to feed an electronic governor which controls the train speed at 22 mph on 270 code by motoring below this value and applying the electro-pneumatic brake if a higher speed is reached on downhill sections.

The EP [electro-pneumatic] brake is not arranged to be fail safe and the various safety devices on the train (e.g. Deadman's handle, passenger emergency valves, etc.) operate on a proprietary pneumatic brake. The automatic train operation safety system, therefore, uses the pneumatic brake and applies the emergency brake when required by releasing air from the brake pipe, which is continuous down the train. This causes triple valves on each car to operate, admitting air from auxiliary reservoirs to the brake cylinders.

A trip valve provides the link between the automatic train operation safety circuits and the pneumatic brake, and is held closed by feeds from the code relays. It has four somewhat conflicting design requirements:

With no supply to the coil, and over the normal range of brake pipe pressures, the force tending to open the valve must be great enough to eliminate any possibility of the valve 'sticking-in'.

The 'way through' the valve should be equivalent to a 1" diameter pipe.

The valve current should be such as can be handled by safety relay and mechanical governor contacts.

A delay in the drop-out of the valve of the order of 1 sec after opening of the relay or governor contacts should be achievable. This is to cover the delay which occurs during the change from one code to another.

The valve, which has been specially produced, is a slightly enlarged version of a current design of EP brake magnet valve. Brake pipe air is connected to the central chamber in the valve body and is

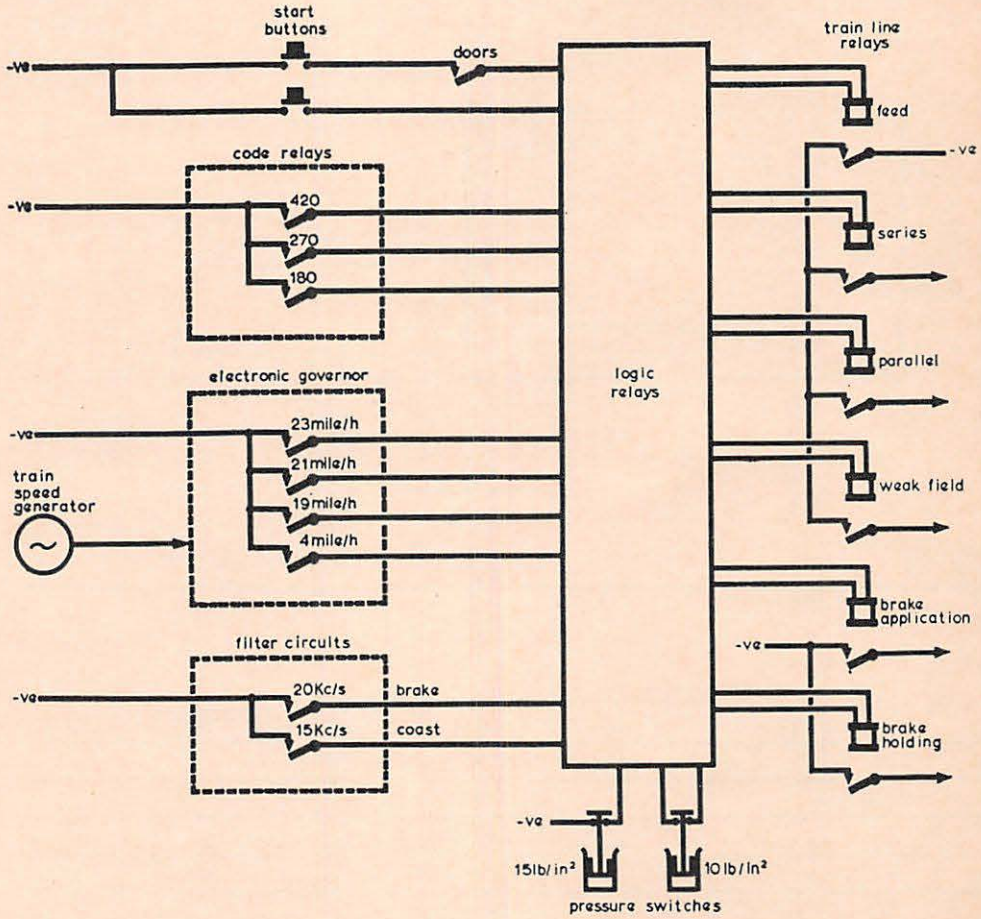


Fig. 5—Diagram to show how train is started and its speed controlled.

retained as long as the lower valve is lifted against its seat. When de-energized the valve drops and air escapes to atmosphere via the chamber between the lower valve and diaphragm. The upper valve merely acts as a stop in this version. Both valves are of synthetic rubber.

The valve stem assembly is held central by guides which can deflect to permit the vertical movement. Adjacent to these are the diaphragms which partially balance the valve. The degree of balance varies depending on the position of the stem assembly. In the 'closed' position, with 65 lb/in^2 pressure in the brake pipe the unbalanced force would be 250 lb but the net force allowing for the diaphragm effect is 25 lb in the energized position and 5 lb in the de-energized position.

The encapsulated coil is mounted above the valve body, the moving core being integral with the valve stem. This latter is located by the flexible guides but a PTFE ring is let into the base of the coil to prevent any possibility of the core rubbing at this point.

Below the valves is an arm which operates the micro switches which are used for interlock contacts.

When running at the controlled speed on 270 code the electronic governor holds the train speed within ±2 mph of the average of 22 mph, but neither the governor nor the EP brake which it controls are fail safe. A mechanical governor of proved reliability is, therefore, brought into action on 270 and 180 code to open circuits to the trip valve if a speed of 25 mph is exceeded. This is a version of a governor which has been used with cab signalling installations on a number of railway systems for many years, but whereas it is normally axlebox mounted, clearances on London Transport tube stock preclude this arrangement. It has, therefore, been adapted for gear drive from the center portion of an axle, using a mounting similar in principle to that used for traction motors. All four axles on each motor car already carry traction motors and it has, therefore, been necessary to mount the governor on the adjacent trailer car. The governor is provided with easily set adjustment to allow for wheel wear and to retain the calibration within ±2%.

Fig. 6 shows a speed-distance diagram for a train running between two stations, the second train following closely behind the train in front, and at the bottom of the diagram are shown the safety codes applied to the track circuits under the various conditions of positions of the two trains. Train No. 2 on the diagram, having been started from station 'A' by the train attendant pressing the starting buttons, accelerates to full speed and continues to motor until it reaches the coasting point at which the motors are switched off. It then coasts until, by reason of track occupation ahead (train No. 1), it reaches a 20 kc command spot; this causes a normal brake application. The speed of train No. 2 is then reduced by the brake application and if train No. 1 does not move out of the station train No. 2 would be brought to a complete stop to wait for the track to clear. It can be assumed, however, that the train ahead is already moving out of the station and the first track circuit clears, putting 270 code on to the track for the second train. This occurs just after the speed of train No. 2 has fallen below 22 mph and the brakes are released and the train then proceeds to follow into the station at the governed speed of 22 mph, the safety signalling maintaining a braking overlap of sufficient distance to bring the train to rest from a speed of 25 mph. Train No. 2 running into the station at its governed speed of 22 mph passes over the first braking command spot, but as the speed is so much lower than the command speed no response is called for and the train equipment ignores this command spot. Similarly, for the successive command spots until the train reaches the command spot at 2.5 kc or 25 mph. This spot initiates a normal brake application and the train then commences its braking to stop in the station, the speed is checked at successive braking command spots and, the brakes being adjusted according to the comparison of the train speed and the command spots, the train is brought to rest at the same point as it would have done had it come in at the full speed run.

It is virtually impossible to provide code on depot tracks, and arrangements had also to be made to permit clearance of a train following failure of track or train equipment. A further set of mechanical governor contacts have, therefore,

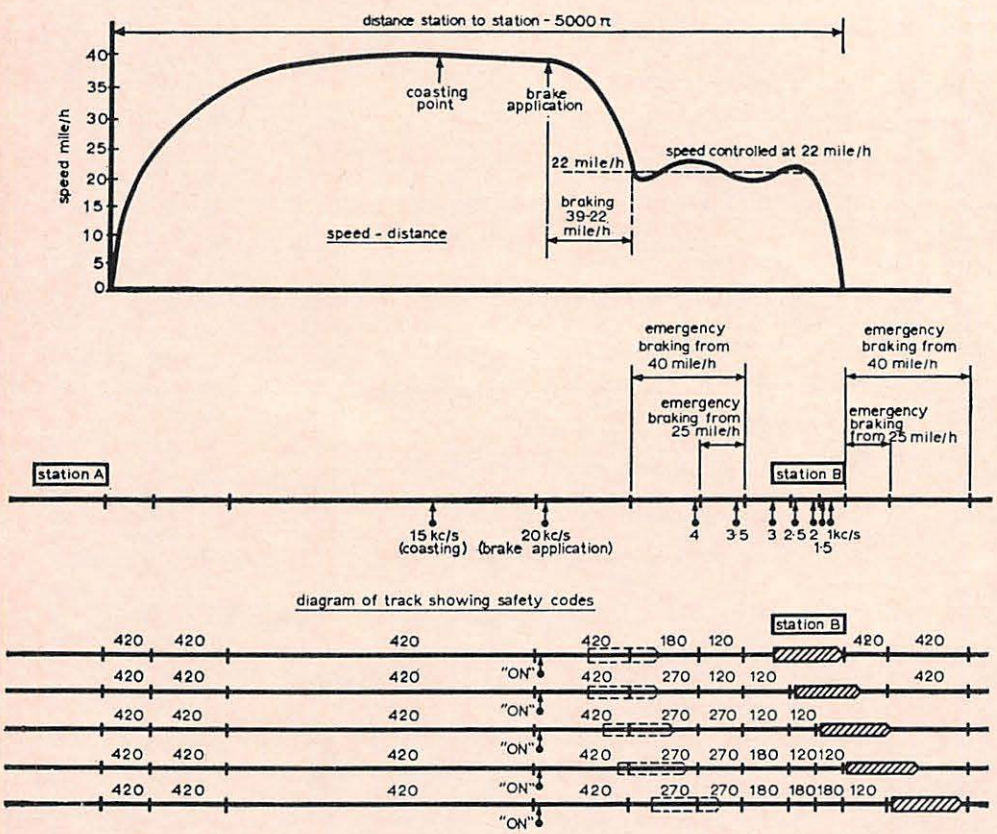


Fig. 6—Speed-distance plan of two trains with safety codes applied to track circuits.

been provided which open at about 10 mph. When working into depot or past a signal at danger the train operator must lift a 'flag' switch (termed the 'slow manual switch') which is visible at the front of the train. This, in manual driving only, provides an alternative feed to the trip valve through the 10 mph governor contacts. A warning is provided to the train operator about 1.5 mph below the tripping speed to assist him in observing the restriction.

The northern section of the Hainault Loop between Hainault and Woodford has been operated as a separate self-contained 'shuttle' service ever since the line was elecrified in 1949.

Prior to the introduction of automatic working the service on this line was operated by 4 trains during the peak and 2 trains during the off-peak periods.

TRAINS HAD 4 CARS

The trains were composed of 4 cars. The line provides examples of most features commonly to be found in a railway layout and was thought, therefore, to be particularly well suited for the trial of the third stage of London Transport's automatic train operation developments.

Fig. 7 shows a plan of the line which comprises double track branching off from the main line just north of Woodford station. At Woodford station trains are reversed by proceeding to a siding and returning to the opposite platform. At Hainault trains reverse in the single platform. There are three intermediate stations. The service on the line is provided by four automatic trains of tube stock type. Before being converted for the operation of automatic trains the line was signalled with London Transport's standard signalling of 2-aspect color light signals, track circuits and power operated switches. This wayside signalling has been retained as the line is also used for the passage of a number of manually driven trains which require to proceed to and from the car depot at Hainault. The arrangement of the automatic train working has been provided to conform to the fixed signals. The section of line has been provided with coded track circuits throughout and with the necessary command spots

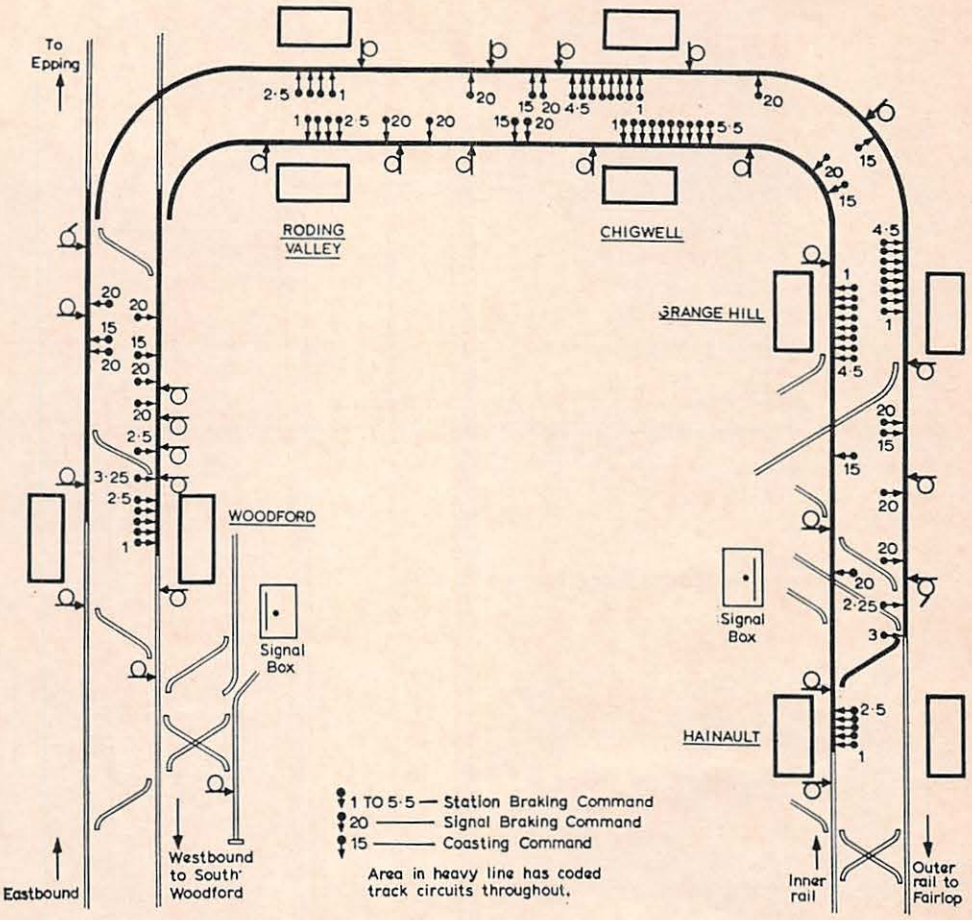


Fig. 7—Plan of Woodford-Hainault line on which experiments were conducted.

to govern the automatic working of the trains. There were existing signal towers at Woodford and Hainault and alterations have been made to the circuits of the signalling at these towers to provide for the application of codes to the track circuits through the interlocking areas. The speed of the train passing over the junction just north of Woodford is required to be regulated to 22 mph and the speed through the crossover approaching Hainault station is regulated to the value of 15 mph. In addition to these permanent speed restrictions there are two temporary speed restrictions on the line on account of work in progress on the banks. These restrictions require the speed of 22 mph to be employed, and the arrangements of the automatic command equipment have been made to provide for the train speed to be regulated to comply with these speed restrictions.

At the Hainault end of the section the train automatically runs through the crossover into the platform and stops automatically. The train operator then reverses the train equipment for the train to proceed in the opposite direction and when the starting signal clears he operates the starting buttons and the train commences the return run.

At the Woodford end of the line when the train has automatically stopped in the station the operator then changes over from automatic driving to manual driving of the train and drives it into the siding; this is at the governed speed below 25 mph, 180 code being received. In the siding the operator reverses the train equipment and when the outgoing signal is cleared he manually drives the train through the crossovers into the platform and at this point changes over again to automatic working. The automatic running of the train is then resumed for the passage through the line back to Hainault.

In the event of a speed being required of a different value from that provided by the governed 22 mph speed, for example for a speed restriction over a shortsection of line, it is possible by suitably positioning command spots to achieve practically any speed desired. For example, the crossover approaching

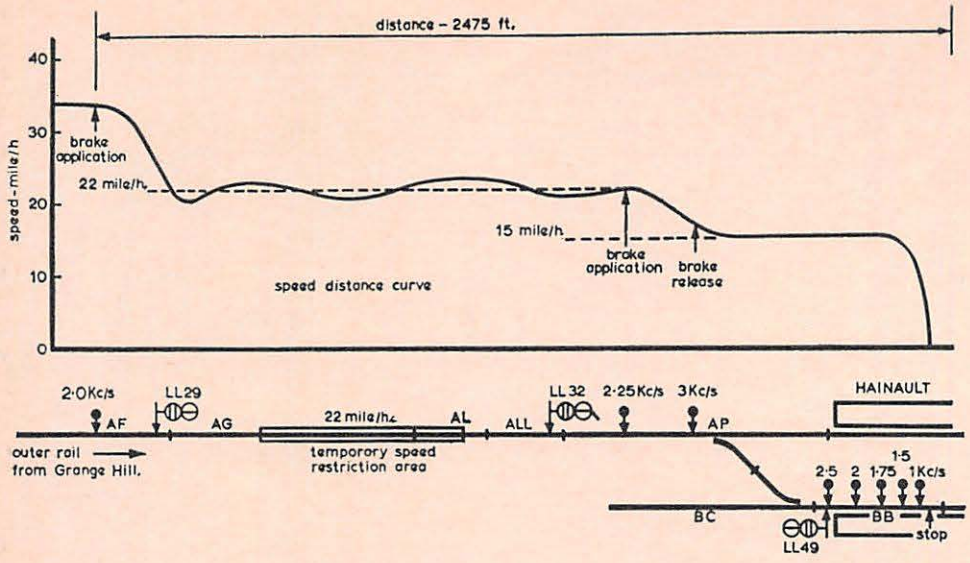


Fig. 8—Track approaching Hainault with speed restricted area and command spots.

Hainault station is constructed for a calculated speed of 15 mph, and running at an average of this speed is achieved by means of two command spots. The arrangement is shown in Fig. 8. It so happens that before reaching the crossover in question there is a length of track over which a temporary speed restriction of not more than 25 mph occurs and the speed of the train over this section is regulated by means of the automatic speed control on the train to 22 mph. Then when the train approaches the crossover a command spot of a frequency of 2.25 kc is provided as the speed of the train approximates to this speed. This will cause a normal brake application and the switching off of the motors if they were on at the time. Calculations have shown the distance that the train takes to reduce to between 16 and 17 mph and at this point another braking command spot of a frequency of 3 kc is fixed. The application of the brakes will have reduced the speed of the train at this point and so when reading the 3 kc command the comparator on the train will determine that a brake release is required and the brakes will be released. This enables the train to continue coasting at approximately 15 mph through the crossover and into the station where it is stopped by the station command spots in the usual manner. Because of the low approach speed an intermediate value of station command spot 1.75 kc has been provided to insure suitable application of brakes.

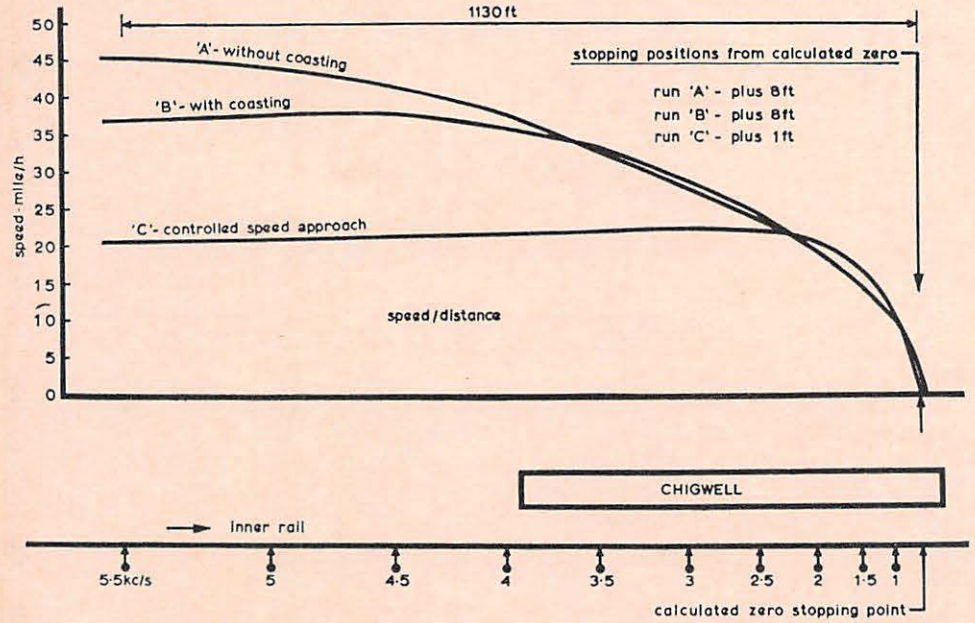


Fig. 9—Speed-distance curves resulting from experiments with braking.

From the opening of the service of automatic trains on the Hainault Loop advantage has been taken to continue tests with the working of the trains. One test taken demonstrates the working of the automatic train under various conditions of speed. The section between Grange Hill and Chigwell is 0.835 mile and is on a slightly down gradient, therefore providing a suitable section for demonstrating any different speeds of approach to Chigwell station. Tests have been carried out with the train accelerating the whole distance until the first braking at Chigwell has been applied, and also under the normal conditions with the motors cut off at the coasting point and, therefore, a reduced speed of approach, and finally with a slow speed approach resulting from the train having been checked at the signal approaching Chigwell station. The results in the form of the speed-distance curves are shown in the diagram Fig. 9. It will be noted that the stopping distances from the calculated zero are 1 ft, 8 ft and 8 ft.

It should be particularly noted that in designing the automatic train equipment for London Transport much more emphasis has been placed on utilizing a high average rate of braking from the commencement of braking right up to the stopping point than emphasizing a very high degree of accuracy in the actual stopping, as it is felt that this high accuracy could only be achieved by reducing the speed of a train sooner than is otherwise required, thus enabling an accurate calculation for the final braking to be made at the expense of the average speed of the run into the station. This could have an adverse effect on the service on a close headway line.

Introduced into passenger working on 5th April 1964, the automatic trains have, up to 13th June, covered some 94,052 car-miles in service and the results achieved give prospect of it being possible to achieve a good standard of reliability with such equipment in passenger train service. **RS&C**

(Continued from page 10)

maintenance, Lima, Ohio, is appointed assistant signal supervisor at Huntington, Ind.

• PENNSYLVANIA: **J. A. Early,** engineer electronics, Philadelphia, appointed engineer communications and signals, Chicago, succeeding **C. P. Huth,** deceased.

Supply Trade News

• C&D BATTERIES has opened a new factory branch office at 169 S. Lexington Ave., St. Paul, Minn. **John A. Hansen,** the new manager, will have sales responsibility covering Minnesota, North and South Dakota and western Wisconsin.

A. Gordon Thomson
Gen. Railway Signal

E. J. Pleszko
Preformed Line Prod.

• HOWARD & GOULD CO. have appointed Petch & Co., 1208 Wadsworth Blvd., Denver, Colo., as sales representatives serving the Rocky Mountain area. Vale Enterprises Ltd., 352 Dorval Ave., Dorval, Que., have been appointed sales representatives for all of Canada for H&G products.

• GENERAL RAILWAY SIGNAL CO.: **Jack E. Rupp,** project manager of US&S, has been appointed manager, urban transit markets. **A. Gordon Thomson,** supervisor application engineering department, has been appointed assistant to vice-president engineering.

Mr. Rupp graduated from Carnegie Institute of Technology in 1942 with a bachelor of science degree in electrical engineering. He joined Union Switch & Signal in 1947 and served in various engineering, research and market capacities. His latest position was that of assistant to vice-president—general manager, and project manager.

(Please turn to page 36)

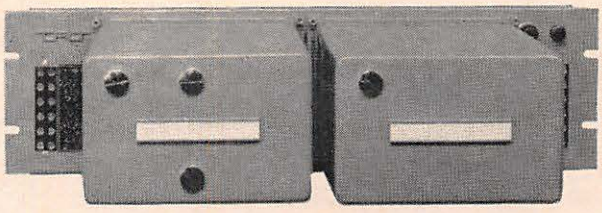
Norelco® -TELEPHONE DIVISION-

STACKABLE SYSTEM

UP TO 10 CHANNELS ON 1 PAIR!

7 TR 001

TRANSISTORIZED CARRIER SYSTEM FOR OPEN WIRE LINE OR CABLES

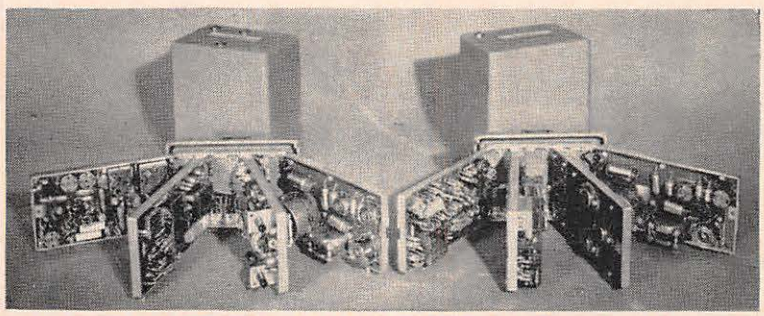


The 7 TR 001 system is a completely transistorized carrier system permitting up to 10 carrier channels to be added one by one to the VF circuit on each pair of an open wire route. Thus the channels need be purchased only as and when required.

• Individual channel dropping. In the system, the channels may be dropped individually or in groups at one or more points along the line.

• Great operation flexibility. Transportation, installation and maintenance of the equipment are extremely simple and do not require specialized personnel.

• Installation. The 7 TR 001 carrier equipment panels are arranged to mount on standard 19 inch relay racks.



NORTH AMERICAN PHILIPS COMPANY, Inc.
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Phone : Oxford 7-3600 Cable : PHILYORK

3511

Fundamentals of Electricity – QUESTIONS

Note: Figure in parenthesis refers to data sheet number.

1. Experimenting with static electricity, we learn that unlike charges _____ and like charges _____. (28)

2. Usually, the ability of a conductor to transmit electricity will vary directly with the area of its _____. (28)

3. Current flow is measured in _____. (29)

4. Electrical force is measured in _____. (29)

Current Flow

5. There are three fundamental factors present in every electric circuit, _____, _____ and _____. (30)

6. Simple Ohm's Law formulas are I = — ÷ —, R = — ÷ —, and E = _____ × _____. (30)

7. If we wish to reduce the current flow _____ must be added to the circuit. (30)

8. In electrical work, power is measured in _____, and the time in _____, so that the total work is watts times hours or watt-hours. (31)

9. Watts are the product of _____ times _____ _____. 1,000 watts equals 1 kilowatt. (31)

Batteries

10. _____ cell batteries transform _____ energy into _____ energy, and which may have the original materials restored by passing current through them in the reverse direction, thus storing _____ energy as _____ energy. (32)

11. A _____ cell is one which transforms _____ _____ energy into _____ energy, depleting its elements in the process. (32)

Storage Batteries

12. The capacity of a storage battery is reduced at low temperatures due to the increased _____ and _____ of the electrolyte, but no permanent harm results if freezing is avoided. (34)

13. Rectifiers are used for converting _____ _____ _____ to _____ _____. (47)

Magnetism

14. _____ and _____ have strong magnetic effects and are referred to as magnetic materials. (51)

15. Materials, such as hardened steels, which retain their magnetism after the inducing field has been removed, are known as _____ magnets. (51)

Magnetic Terms

16. The ease of passage of or ability to conduct flux is known as _____. (52)

17. _____, the opposition to the passage of flux in a magnetic circuit is akin to resistance in an electric circuit. (52)

18. The lower the reluctance (or the higher the permeability) the less _____ _____ is required to establish the field. (52)

19. Another term applied to magnetic lines of force is _____. (52)

20. The _____ rule illustrates the relationship between direction of current in a conductor and magnetic field around it. (53)

Conductor in Magnetic Field

21. When we combine an energizing coil with some sort of iron core we have an _____. (54)

22. There must be a voltage or electromotive force _____ _____ in the conductor in order to cause a current to flow. This is known as _____ _____. (54)

The Transformer

23. A very useful and common application of mutual inductance is the _____. (57)

24. We have learned that when a conductor cuts across a magnetic field, _____ _____ is induced. (57)

25. The commutator is in reality a mechanical _____ which supplies _____ _____ current at the brush connections. (57)

AC Generator

26. AC generators are frequently called _____. (58)

27. A rotating coil in a magnetic field will convert _____ _____ energy into _____ energy. (59)

28. The shunt wound motor has its _____ coil and _____ coil connected in parallel across the input voltage. (59)

29. In a series wound motor, the armature and the field coils are in _____. (59)

WHAT'S THE ANSWER?

Signal Testing

Q. When testing a signal installation before placing in service: (a) what procedure is used to verify each vital circuit is free of grounds? (b) When breaking down vital circuits, do you verify electrically that a contact on a relay is the one assigned on the circuit plan?

A. All circuits are meggered before being placed in service. In addition, voltmeter tests are made between all battery and ground.

In making the breakdown test, each individual circuit is opened at each break. This is done by actually disconnecting the wire and observing that all battery is removed from circuit under test. The relays, levers, switches, etc., are then operated to assure that the circuit operates as intended. If the circuit under test is normally de-energized, battery is applied at the feed end temporarily for test purposes.

R. J. Miller, Circuit Engineer, Baltimore & Ohio, Baltimore, Md.

A. (a) Cable is meggered for crosses and grounds after cable ends have been terminated. Tower and case wiring is checked by observing voltmeters connected between each side of supply source and ground while breakdown check is being made. Meters are also connected and observed while operating check is made at time of cut in.

(b) The breakdown check is made electrically and the contact assignments shown on the circuit plan are verified. We do not use any wiring diagrams and all work is done directly from the circuit plan.

R. C. Bailey, Assistant Engineer-Signals, Richmond, Fredericksburg & Potomac, Richmond, Va.

Hunting Grounds

Q. How do you hunt grounds in signal or communications circuits?

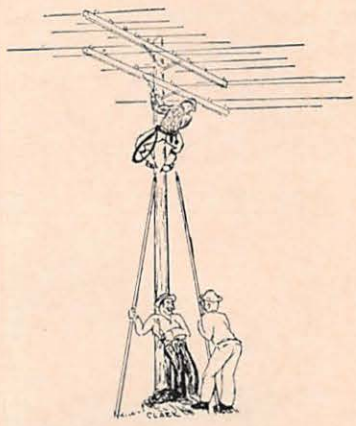
A. On this property, the signal circuits are checked constantly for grounds. This is done with a voltmeter with all circuits intact. When a circuit is grounded, we use the process of elimination to determine its location. The line circuits are disconnected from top of the line arresters and the underground cable disconnected to isolate the battery and local wiring. During this operation, a check with the voltmeter should determine which portion of the circuits may be sectionalized between terminal points to further confine the ground. The final search is performed with a 500-volt Megger insulation tester.

C. C. Evans, Chief Draftsman, St. Louis-San Francisco, Springfield, Mo.

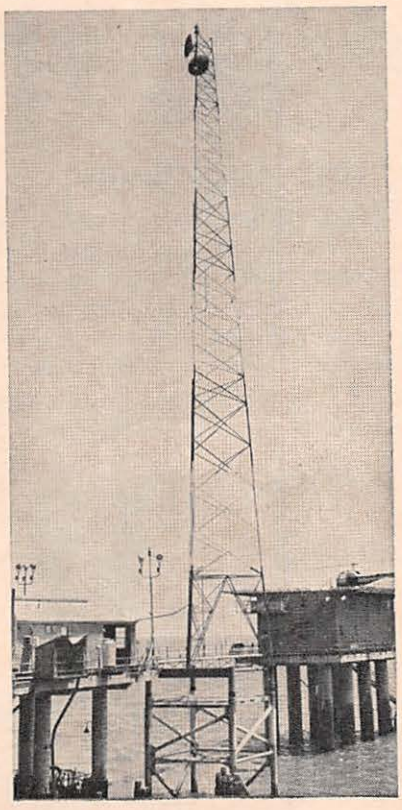
A. We use the following procedure when hunting DC grounds in signal circuits:

When hunting a negative ground, the negative lead of a voltammeter is placed on ground and the positive lead on the positive side of local battery. A momentary 5-ohm shunt should be placed on common and a control circuit from each direction. If an increase in meter reading is detected, you should go in the direction where the shunt

(Please turn to page 44)



"Why don't you clowns go on up the track and help Sam?"



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A series of ROHN micro-wave towers, used on Shell Oil Company offshore platforms near the Louisiana coast, took on the full fury of "Hurricane Hilda" and withstood the test!

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Altec offers railroad communications engineers a complete line of VF transmission products that have been proved through the years by major telephone companies. Each piece of equipment represents the most advanced features available, such as all-transistor circuitry, small size, low heat, and simple installation. Quick delivery from stock eliminates waiting and back-ordering.

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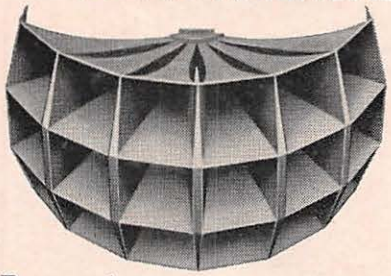
Plug-in Repeater Amplifiers are all-transistor, do not require 130 v power supply. Only 1⅝" x 1 11/16" x 5 3/16". ■ **Plug-in Transformers** include Hybrid Transformers with high trans-hybrid loss and Line Transformers with impedance matching drop side to telephone. ■ **Plug-in Networks** include compromise and precision networks. ■ **Plug-in Line Equalizers** compensate for frequency-amplitude characteristics in cables or lines. ■ **Plug-in Auxiliary Devices** include pad adapters, pad control relays, loop-back relays, idle-circuit disabler, and filters. ■ **Plug-in Attenuators** introduce fixed loss in 4-wire paths. ■ **Power Supplies** energize up to 100 repeater amplifiers. ■ **Mounting Panels & Assemblies** mount amplifiers, networks, equalizers, or repeaters.

OTHER RAILROAD SOUND EQUIPMENT



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For maximum intelligence at all times, Altec has developed NOALA®, which automatically increases or decreases sound system output to compensate for variable high noise such as passing trains. Altec's noise-cancelling microphones, for radio or line, eliminate ambient noises which interfere with intelligibility of voice-transmission.

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NEWS BRIEFS

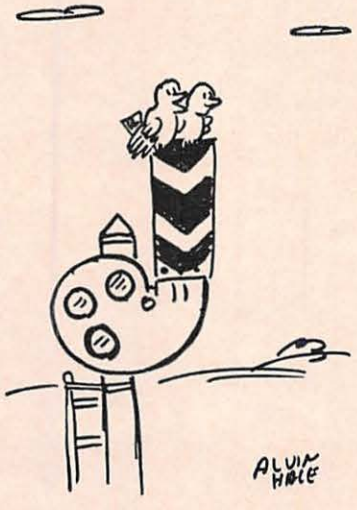
(Continued from page 33)

Mr. Thomson joined GRS as a co-op student in 1946 and three years later was promoted to application engineer. He was appointed an application engineering group leader in 1955. He was appointed supervisor in application engineering in 1963. In his new position, Mr. Thomson will coordinate activities between the engineering, application engineering and engineering services departments.

• NOLLER CONTROL SYSTEMS INC. has appointed C. W. Silver Co., Salt Lake City, Utah and Twin Falls, Ida., as sales representatives for the states of Utah, Nevada and southern Idaho. Gordon McLaren & Associates, Inc., Mercer Island, Wash., have been appointed sales representatives for the states of Alaska, Oregon, Washington and northern Idaho.

• PREFORMED LINE PRODUCTS CO.: **E. J. Pleszko** has been appointed manager, new products department. A graduate of Ohio University with a degree in mechanical engineering, Mr. Pleszko joined Preformed in 1958 as project engineer. Subsequently he was appointed assistant manager, new products department.

• RAILROAD RUBBER PRODUCTS INC.: This company was incorrectly identified in Product News item on urethane end post appearing in RS&C May 1965, page 32.



"Get ready for a thrilling ride. Here comes a train."

PRODUCT NEWS

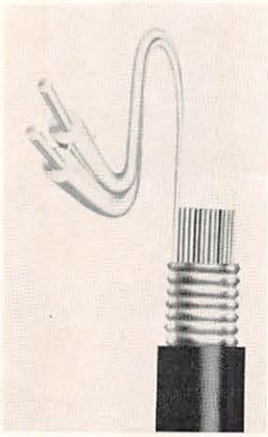
Derrick Truck **RS&C 7-1**

A series of heavy duty digger/derricks PC-1-F, when equipped with various options, can provide a complete pole line maintenance truck. Options include single (3,000 ft-lb max torque) or 2-speed digger (max torque, 7,030 ft-lb), body mounted or boom tip winches, pole claw, 1-man fiberglass bucket, remote controls for the bucket, and an auger shaft for power-installed screw anchors. *Pitman Manufacturing Co.*

• TV CONSOLES: A new brochure E-487A describes closed circuit TV remote control consoles. These units may be used to remotely control TV cameras. Controls include manual or automatic light sensitivity, focused and beamed, as well as intercom controls to the remote camera location for talking to persons in the camera area. *Motorola Communications and Electronics Inc. (CP-7-10)*

Crossing Recorder **RS&C 7-2**

Model 3100 recorder provides a visual record that flashing-light signals are operative at highway grade crossings. The equipment records presence of a train on approach circuit, the island circuit over the crossing and departure, as well as an indication when the lights are operative. The solid state unit operates off 117 volts, 60 cycles AC or 10 volts DC. The amount of recording paper tape provided will last 30 to 60 days at a normally active crossing. *Racon Equipment Inc.*



Multipair Cable **RS&C 7-3**

Patented UniPair construction extrudes color coded plastic insulation on both conductors of a pair at the same time and also forms a web connecting the conductors.

During the extrusion process, both conductors are under equal tension, so a substantial improvement in resistance unbalance is obtained. Because both conductors in a pair are attached, they remain equal in length throughout such fabrication stages as "pair twist lay." These uniformities obtained with UniPair construction are providing this new telephone cable with better transmission characteristics, including improved noise and crosstalk levels. Of special note is the considerable improvement in the crosstalk level of the "worst pair combination."

Under the UniPair construction concept, both conductors of the pair are insulated simultaneously and joined together by a thin web while maintaining the standard color code. UniPair telephone cable is available in 26, 24, 22 and 19 Awg conductors. *Whitney-Blake Co.*

• COATINGS: A new brochure #6325-R includes descriptions and

Circle numbers for more information about products advertised on pages **1 2 3 4 6 7 9 11 12 33 35 36 39 40 41 42 43 44 47 48**

Circle numbers for more information about products described on pages 37-38, 40-42 and marked **RS&C 7-1 -2 -3 -4 -5 -6 -7 -8 -9** and current publications described on pages 37-38 and 40-41 and marked **CP 7-10 -11 -12 -13 -14.**

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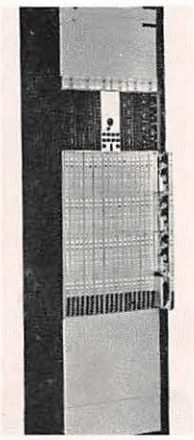
PRODUCT NEWS

colors available of chemical, acid, abrasion and water resistant coating paints. *Rust-Oleum Corp. (CP-7-11)*



Multiplex **RS&C 7-4**

A new multiplex system for radio or line transmission uses single-sideband suppressed-carrier frequency-division to provide up to 960 HF channels. Available in 60-channel groups, the system consists of 20 plug-in trays. A single tray is equipped with three voice frequency channels and associated signaling circuitry.

A new construction technique used in the K-65 provides accessibility from the front of the rack and enables major equipment additions to be achieved without access to the rear of the racks.

Built-in out-of-band E&M signaling, with a 3,825 cps tone is used in the new K-65. In-band E&M signaling (2,600 cps) is available as a standard option.

New construction features include parallel amplifiers, automatic and manual switchover carrier and signaling generators and redundant power supplies. *ITT-Kellogg.*

Service Body **RS&C 7-5**

Designed to provide compact storage space, full rearview visibility and lighter weight, a new line of low-silhouette service bodies features all-welded unit construction, stationary fender-skirts and flush compartment door panels. A complete range of models is available for pick-up chassis in weight classes from ½ to 1 ton. The body is furnished complete with side compartments, floor, reinforced bulkhead and tailgate. The all-steel units are treated for durability with a phosphatizing process plus tough primer coat both inside and out.

Protection against theft and weather is provided by 6 lockable compartments, 3 on each side, with lap-seal doors, top drip-mouldings and rain shielded hinges. Morrison's unique interlocking curl-hinged doors foil tampering and provide lasting ease in opening and closing. All door latches include high quality tumbler locks, keyed alike.

Extra convenience is found in shelving in forward vertical com-

(Please turn to page 40)

"IT'S 'MOST USEFUL' TO US,"

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Atlantic Coast Line
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CENTRALIZES
HOT BOX CONTROL
AT CTC CONSOLE

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DATA STORAGE AND COMMAND SYSTEM

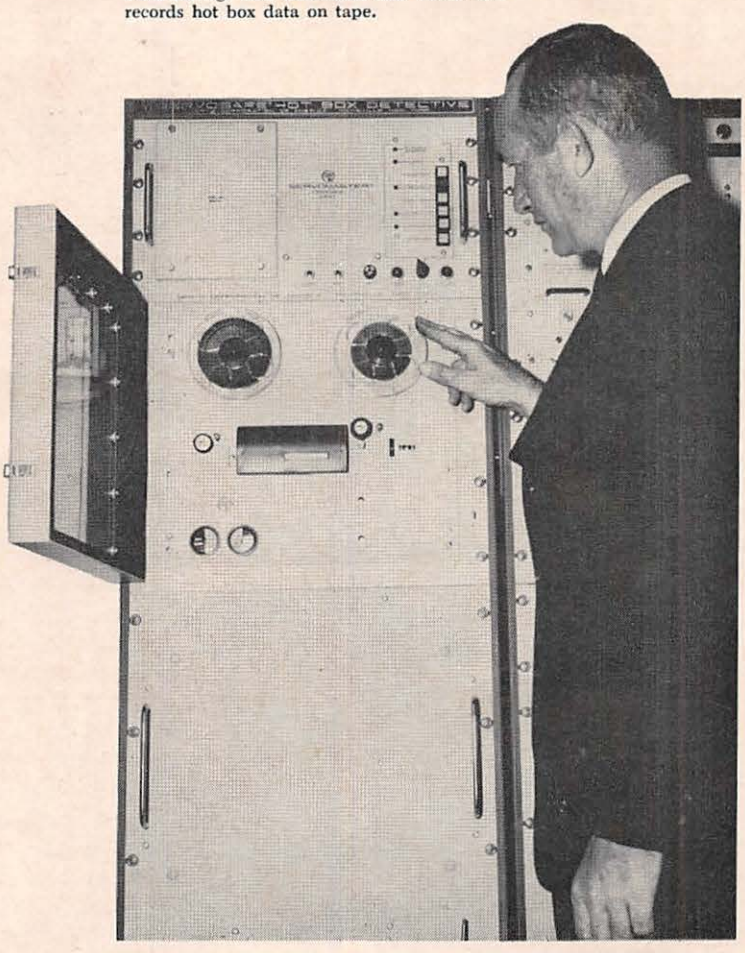
Servo salutes the ACL! Progressive ACL management has scored another important first. Protected by a strategic network of sensitive infrared SERVOSAFE® Hot Box Detectives* since early 1959, the Atlantic Coast Line is first to add the latest major breakthrough—the amazing SERVOMASTER® Data Storage and Command System.

The new Servomaster system permits the CTC dispatcher to supervise, monitor, and control a network of remote unattended Hot Box Detective* installations. An alarm lamp on the CTC console immediately alerts the dispatcher to any detected hot boxes. Trains can thus be stopped in a manner causing least disruption of traffic.

Train information is stored on magnetic *tape* at each Detective site. A *single* carrier frequency feeds in information from all detectors. Only *one* graphic chart recorder is required in the CTC dispatcher's office to display hot box data reported by the entire network.

In the words of ACL President W. Thomas Rice: "Reducing the cost of the hot box is like adding extra revenue."

Chief Engineer Communication and Signaling R. D. Liggett inspects new SERVOMASTER® Data Storage and Command unit which now records hot box data on tape.



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SERVO CORPORATION OF AMERICA

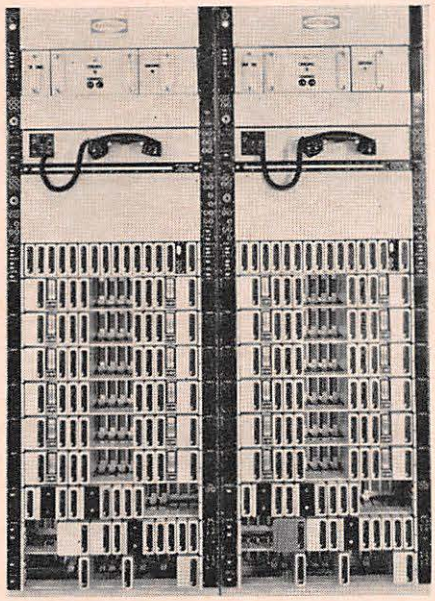
*Protected under one or more of the following U.S. Patent Nos.: 2,880,309; 2,963,575; 3,028,484; 3,095,171; 3,108,772; 3,108,773. Canadian Patent Nos.: 643,038; 643,091; 690,506; 690,907. Other U.S. and foreign patents pending.

(Continued from page 38)

partments, brackets for shelving in aft compartments, plus a full-length parts tray in the streetside horizontal compartment. Curbside parts tray and all shelves are complete with high roll-edge lips to prevent spilling, and divider tabs which fit and move easily in special slots, for small parts storage. Compartment doors, double panelled and equipped with standard Morrison paddle-grip slam catches, open and close with one hand. Horizontal compartment doors, with chain stops, open to form a handy, level shelf.

The large truck bed space features 4-way safety tread steel flooring, supported on bridge-type cross beams and longitudinals. Tailgate opens on heavy-duty hinge pins to a level position on double chain-stops, or drops down above bumper-step to allow unobstructed access. *Collins Associates.*

• SIGNALING SET: A two-page flyer describes the new card mounted DX signaling set which provides for dialing on a metallic basis over distances up to 50 miles. *Stromberg-Carlson Corp. (CP-7-12)*



Carrier MX **RS&C 7-6**

TMS-2 is a transistorized frequency-division carrier-multiplex equipment. Single-sideband, suppressed carrier techniques are used to combine toll-quality circuits for transmission over radio or cable. TMS-2 equipment exceeds CCITT recommendations, and the equipment can be used to expand other carrier systems meeting CCITT and Western Electric L, N, or BN requirements. TMS-2 can be provided in partial or multiples of twelve channels, and existing systems can be expanded without obsoleting present facilities. Plug-in, printed-circuit modules are used throughout; horizontal shelves guide and carry the plug-in units. Equipment bays can be mounted back-to-back, and all components are fully accessible from the front.

From 3 to 2700 toll-quality circuits composed of voice channels, facsimile, program channels, and wide-band data channels can be transmitted over radio or cable facilities. For low-capacity applications, complete 12- and 24-channel equipments are available in single-rack configurations. *Raytheon Co.*

• CABLE PLOWING: Bulletin 260 describes the use of rubber tired cable layer, model OCLR-T, which may be used for plowing in communications or other types of multi-conductor cable alongside highways or other locations where rubber tired vehicles may be operated. *American Tractor Equipment Corp. (CP-7-13)*

• COMMUNICATIONS TOOLS: Tool specifications brochure 200 describes adjusting, maintenance and production tools for servicing telephone, communications and electronics equipment. Over 450 high-quality carbon steel tools are described. *Jonard Industries Corp. (CP-7-14)*

Utility Truck **RS&C 7-7**

A new utility truck features an aerial boom with a fiberglass bucket plus an earth auger which can be used to advantage in pole line maintenance work. The Polecat utility equipment is mounted on an

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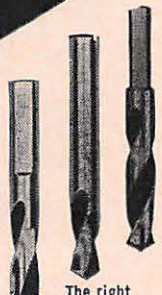

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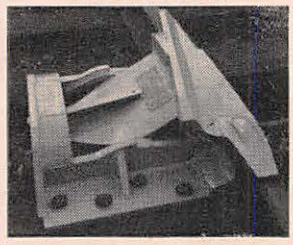

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Hayes Track Appliance Co.
RICHMOND, INDIANA

FWD Blue Ox chassis which provides 4-wheel drive for operation on and off highways.

With full boom extension the Polecat can reach out 23 ft. The digger or earth auger develops 3,000 lbs of torque at 65 rpm. Lifting capacity of the Polecat boom is 9,500 lbs. The fiberglass bucket, when attached to the boom, can put the operator up to 32 ft in the air. Remote controls may be installed in the bucket for the operator's convenience. *Pitman Manufacturing Co.*

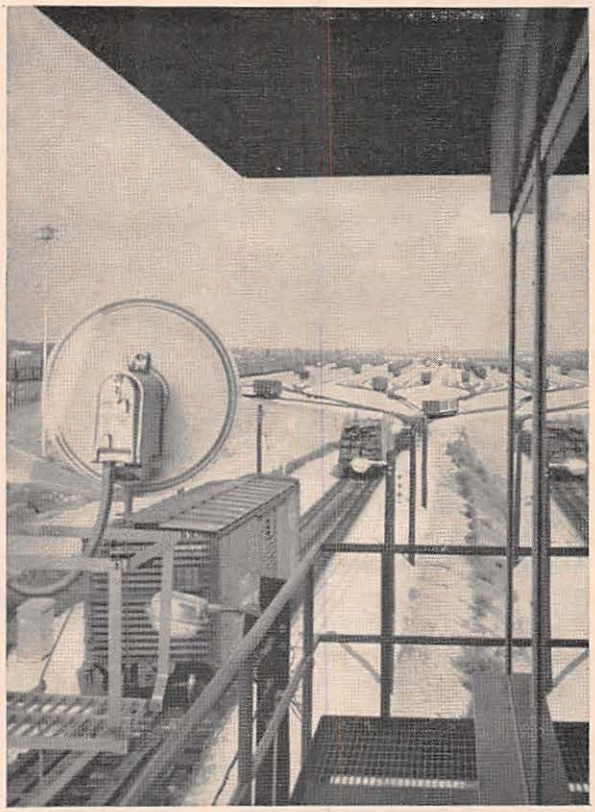
Microwave Antenna **RS&C 7-8**

The Shroudome parabolic antenna can attain as much as 65 db front-to-back ratios in the microwave frequency bands. The Shroudome antenna is available in 10 ft diameter, and shortly will be available in 4', 6' and 8' diameters also. Numerous feed and dome combinations are offered: single polarization, dual polarization, and very low VSWR single or dual polarization. *Mark Products*

TV Camera **RS&C 7-9**

A new television camera features 800-line horizontal resolution. Model

(Please turn to page 42)



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General Cable Corporation, 730 Third Avenue, New York, N. Y. 10017.

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STOCKHOLM SUBWAY TESTS AUTOMATIC PILOT

(Continued from page 23)

1964 car number two was to be prepared and at the same time the test line for automatic operation was to be extended.

Almost all test runs have been recorded by instruments which record motor current, orders from the computer, etc. See Fig. 5. These records have been of great value for the investigation of observed irregularities. A large number of drivers have acted as operators. Most of them have been very interested and well disposed towards the equipment when they have overcome their initial scepticism. Their criticisms have mainly concerned the smoothness of operation.

At this stage of the development there are no tenders available and for this reason nothing but mere guesswork is possible.

The only comparison that is possible is to the installation of the cab signal system. There are, however, great differences owing to the following:

(1) The most expensive part of the automatic pilot, the computer, is intended to be portable, and only one or two are needed per train.

(2) The wayside equipment of the automatic pilot is very simple compared with track circuits and the relay rooms of the cab signal system.

The installation cost for the cab signal system including the car equipment is about 1.2 million Swedish crowns [about $240,000] per mile double track, and a bold guess would indicate that the cost of the automatic pilot will amount to 10 or 15 per cent of that of the cab signal system. That would amount to about 10 million Swedish crowns [about $2,000,000] for the existing network.

It is mentioned above that the line prepared for automatic operation was to be extended in March 1964. The next phase of the development probably is that the automatic train, still two-manned, should be put into regular operation, and if nothing unexpected occurred it would be possible to make a final decision concerning the automatic pilot in May or June 1964. About a year after that the first series-produced pieces of equipment may be put into service.

The pieces of equipment thus installed may be regarded as a relatively uncomplicated device, which may improve and facilitate the running and in that way make the changeover from two-manned to one-manned trains easy in the same way as power assisted steering once brought the one-manned buses within reach. Furthermore, this equipment will be regarded as an important step towards complete automation of the operation of underground trains.

As a result the Stockholms Spårvägar expects:

(1) reduced power cost,

(2) an increase of line capacity, from 30 to 35 trains an hour, and

(3) reduced operating cost owing to the introduction of one-manned trains. **RS&C**

PRODUCT NEWS

(Continued from page 41)

ST-2 can read print as small as pencil ledger entries and transmit a clean picture to a remote monitor as far as a mile away without additional amplification. It will operate in rugged environments—altitudes up to 14 miles, temperatures ranging from freezing to 158 deg F and humidity up to 95%.

ST-2's overall size is 6¼" diameter and 12⅝" length. Weight is 13 lb.

Because silicon solid-state electronics are used throughout except for the vidicon tube and the input stage, the camera affords high operating stability at high ambient temperatures. It is also unaffected by temperature and voltage changes which cause picture shrinkage, fading and blurring. Picture degradation will not exceed 5% in size, contrast or resolution with input power changes as much as 30 volts and temperature variations of 125 deg F.

The molecular circuitry allows incorporating of a binary counter type of sync generator within the ST-2. This binary counter requires no adjustment to obtain the proper count and is insensitive to frequency. The video amplifier bandwidth of 12 mc and a 70-gauss focus field provide the 800-line resolution.

The camera operates at 100 to 130 volts, 50 or 60 cycles. With slight modification, a direct current power source of 24-28 volts can be employed. *Diamond Electronics*

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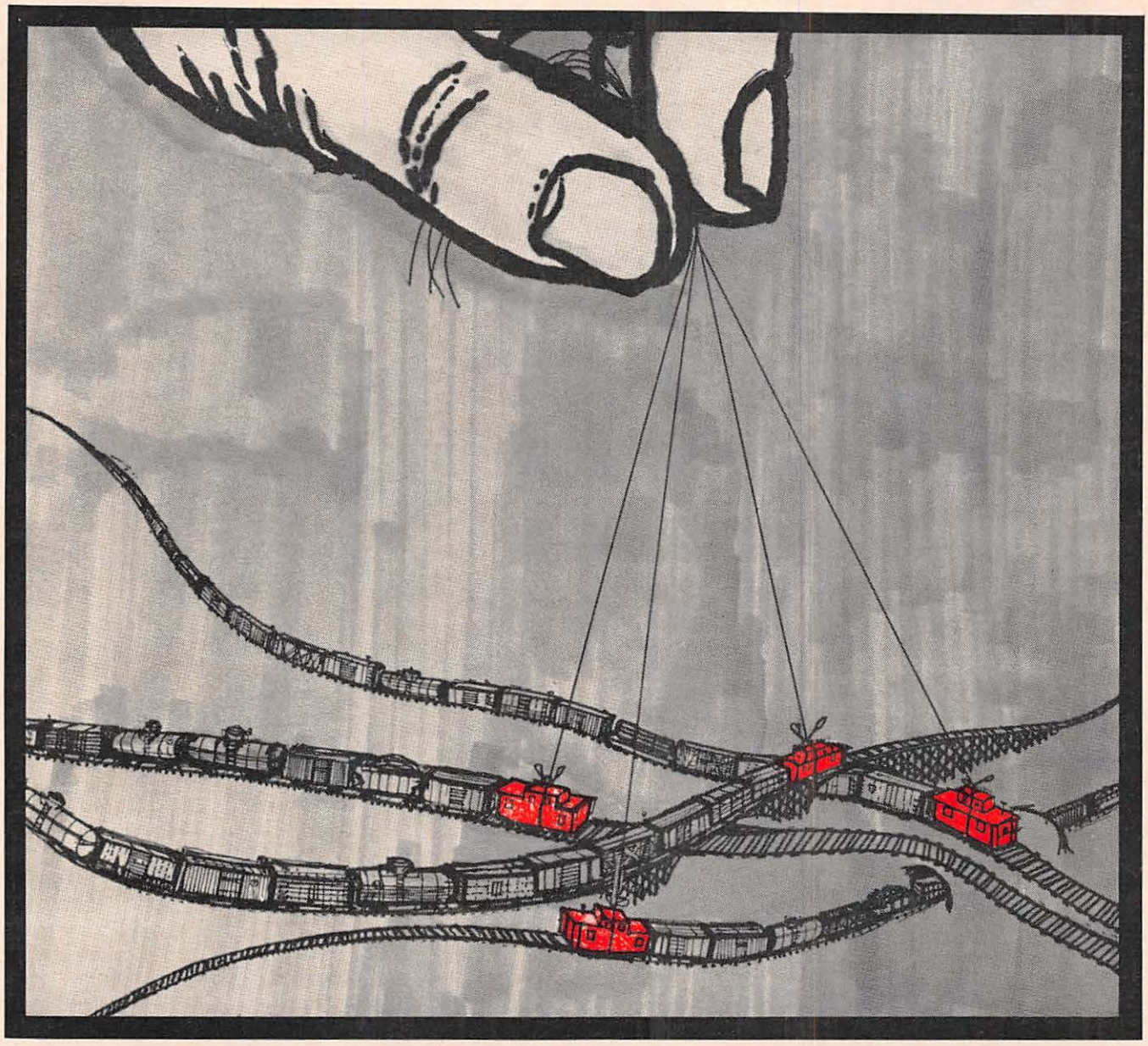

New AE control system uses red cabooses to tell what trains are where

Keeping track of freight trains on the go has never been easy. It is now, with a new AE system that takes advantage of the one constant in a train's makeup—the caboose.

Locate the caboose and you've located the train.

AE does it by converting pulses transmitted from the caboose to meaningful information at a central location. And it operates over standard voice circuits without tying them up. This is achieved by making the signal pulses so short in duration that they do not interfere with normal conversation.

This new AE system, proposed for an Eastern railroad, will have 60 points within a region where each caboose will be asked to automatically identify itself to headquarters. As each caboose reports its location, a lamp on the central display panel will pinpoint its precise whereabouts.

Results: the railroad can exercise far better control over freight movements; and the shipper can be given a more accurate estimate as to when his car will reach its destination.

This is another example of how AE is solving control problems for business and industry. If you would like to know more about AE's control system capability, we have a new booklet which provides more detail. For your copy, write Dept. 578, Automatic Electric Company, Northlake, Illinois 60164.

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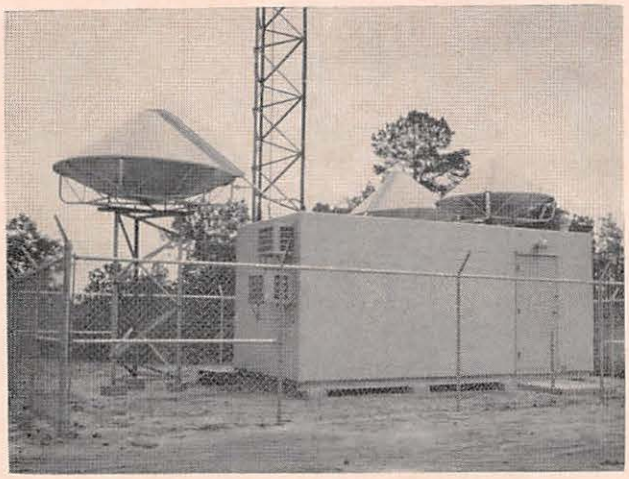

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Servo Corp. of America 39
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Western Railroad Supply Company ..... Cover IV

WHAT'S THE ANSWER?

(Continued from page 35)

created the greatest meter deflection. Test each location in the direction indicated until there is no change in the meter reading. This indicates the ground to be at that location.

The same method is used when hunting a positive ground except the positive lead of a voltammeter is placed on ground and the negative lead on common. Also, a decrease in the meter reading will be detected, instead of an increase, when the momentary 5-ohm shunt is placed.

Apparatus may be falsely energized when current readings are taken so extreme caution should be exercised when making tests.

M. A. Haight
Senior Signal Inspector
Milwaukee Road
Chicago, Ill.

Track Motor Cars

Q. What procedures or rules do you follow for the operation of track motors cars, particularly in traffic control territory?

A. In traffic control territory motor cars are operated on what we term motor car block. Block is issued by the train dispatcher, either a time block which would only be issued if motor car operator wanted to move to a point where no phone communications was available, or what we term a call block if operator wanted to move to a point where phone communications was available.

In either case, trains are not permitted to enter block until time has expired or the motor car operator has contacted the dispatcher in charge and advised his car or equipment is clear of track.

In ABS territory, motor cars are operated on train line only.

B. C. Eaton, Signal Engineer, Denver & Rio Grande Western, Denver, Colo.

A. On the Louisville & Nashville in traffic control territory, track cars are operated by authority of the train dispatcher. Before a motor car is placed on the track the operator

(Please turn to page 46)

Fundamentals of Electricity – QUESTIONS

30. The compound motor has two field windings, one in _____ with the armature, the other in _____ _____ across the line. (59)

Capacitors

31. If the frequency is 60 cycles, it means that _____ seconds is required for each _____ and the direction changes _____ times a second. (60)

32. _____, is the property of a circuit which tends to oppose a change in voltage. (60).

33. A capacitor may be defined as any two conductors separated by an _____ or _____. (60)

34. The unit of capacitance is the _____. (60)

AC Motors

35. The two main parts of AC machines are usually called the _____, the stationary part, and the _____, the rotating part. (61)

36. Alternating current is transmitted and distributed by two wire circuits and two types of three wire circuits. Where there are just two wires it is a _____ circuit of a given voltage, most commonly 110 or 220 volts. (61)

Circuits

37. To connect batteries in _____, the positive terminals of all the cells are connected together, and all of the negative terminals are connected together. (62)

38. To connect batteries in _____, the positive terminal of one cell is connected to the negative terminal of the next, and the output taken from the remaining terminal on each end cell. (62)

39. When resistors are connected in _____ the total resistance in ohms is the sum of the individual resistances. (63)

40. The total resistance of a parallel circuit is always _____ _____ than the lowest resistance in the circuit. (63)

Voltage Divider

41. When a voltage is impressed across two or more resistors in series, the _____ will divide itself proportionally to the resistance. (64)

42. The letter "L" is used to represent an _____ in electrical diagrams and formulas. The basic unit of measure is the _____. (67)

43. The letter "C" is used to represent _____ in electrical diagrams and formulas. (67)

44. Inductance is the property of an electrical circuit that opposes a change in the amount of _____ flowing. (68)

45. Capacitance is the property of an electric circuit that opposes a change in the _____. (68)

R, L & C in AC Circuits

46. _____ causes the current to lag the voltage and _____ causes the current to lead the voltage. (69)

47. We call the effect that capacitance and inductance have on a circuit the _____, symbolized by the letter _____. (70)

Circuit Calculations

48. If a circuit contains both resistance and reactance, we need a term that will include both of them. The term we use is _____, and it, too, is measured in ohms. (71)

49. Impedance can be used in a modified form of Ohms Law to determine voltage and current relationships in AC circuits: E = _____ x _____, I = _____ ÷ _____, Z = _____ ÷ _____. (71)

Graphic Methods

50. In an AC circuit, the power is equal to the _____ times the _____ if the circuit contains only resistance. (71)

51. If the AC circuit contains reactance (capacitive or inductive), multiplyng the volts by the amperes will give what is called the _____ power. (71)

52. The unit of measure of apparent power is the _____ _____. (71)

53. The _____ _____, measured in watts, will be less than the apparent power unless the circuit has no reactance in it. (71)

Power in AC Circuits

54. The ratio between the real power (in watts) and the apparent power (in volt-amperes) is called the _____ _____. (71)

55. Inductance in a circuit results in a _____ power factor, while capacitance causes a _____ power factor. (71)

(Continued from page 44)

must be granted authority by the train dispatcher to occupy the main track between designated points and within designated time limits.

After authority is given by the train dispatcher to a track car operator, the dispatcher must protect the movement within the prescribed time and limits against opposing and following trains and engines. However, no protection is provided by the dispatcher against other track cars. Track car operator must clear main track and restore all switches before the authorized time limit has expired. If necessary to work beyond authorized limits or time, additional time or limits must be obtained before the original time has expired.

The above is covered in our rules and instructions of the maintenance of way department.

J. P. Powell, Engineer Signals
Louisville & Nashville
Louisville, Ky.

Interlocking Check

Q. What is the best and quickest method to use when testing the operation, etc., of an automatic interlocking?

A. Assuming that the question refers to the original checking out of a new automatic interlocking, it is considered that the best way to make sure that the plant is properly installed is to have men at all the signals and to have them in direct communication with the man conducting the test at the diamond. The tracks should be shunted to simulate train movements and the signal indications called in to the man conducting the test. Unlike British law, I consider that a new signal plant which is to be placed in service is guilty until proven innocent. Therefore the word "quickest" should really be avoided and I believe the questioner really means the most expeditious method.

D. H. Green
Engineer of Signals
Canadian National
Montreal, Que.

A. Our method of testing an automatic interlocking is as follows:

"I appreciate your offer, but we're not interested in adding any help right now."

Station one man with two shunts at each home signal to observe signal indications and do shunting.

Station two men at main crossing case to direct tests and check integrity of relays as tests are made.

Shunt an approach on track No. 1 to clear signal. *(Signal indications should be checked after each shunt throughout tests).* Shunt all inside track circuits. Simulate a train movement over interlocker on track No. 1 with shunts, leaving receding track section occupied. Release shunts in order applied, checking directional release. Operate emergency release at crossing for track No. 1 and reverse direction after signal clears. Check all routes in this manner.

Shunt an approach on track No. 1 and after signal clears, shunt an approach on track No. 2, operate emergency release for track No. 2, observing change-over time and signal indications. Check all routes in this manner.

Shunt an approach on track No. 1, clearing signal on track No. 1. False clear signals on conflicting routes, observing signal indications. Check all signals in this manner.

Check the following: loss of shunt protection, grounds, voltage on lamp units both AC and DC; also, alignment of lamps, voltage on track relays and main battery supply voltages.

These tests are for an automatic plant with inoperative approach signals. For operative approach signals, additional tests will be required.

W. D. Archer
Chief Signal & Communications Officer, Gulf, Mobile & Ohio
Bloomington, Ill.

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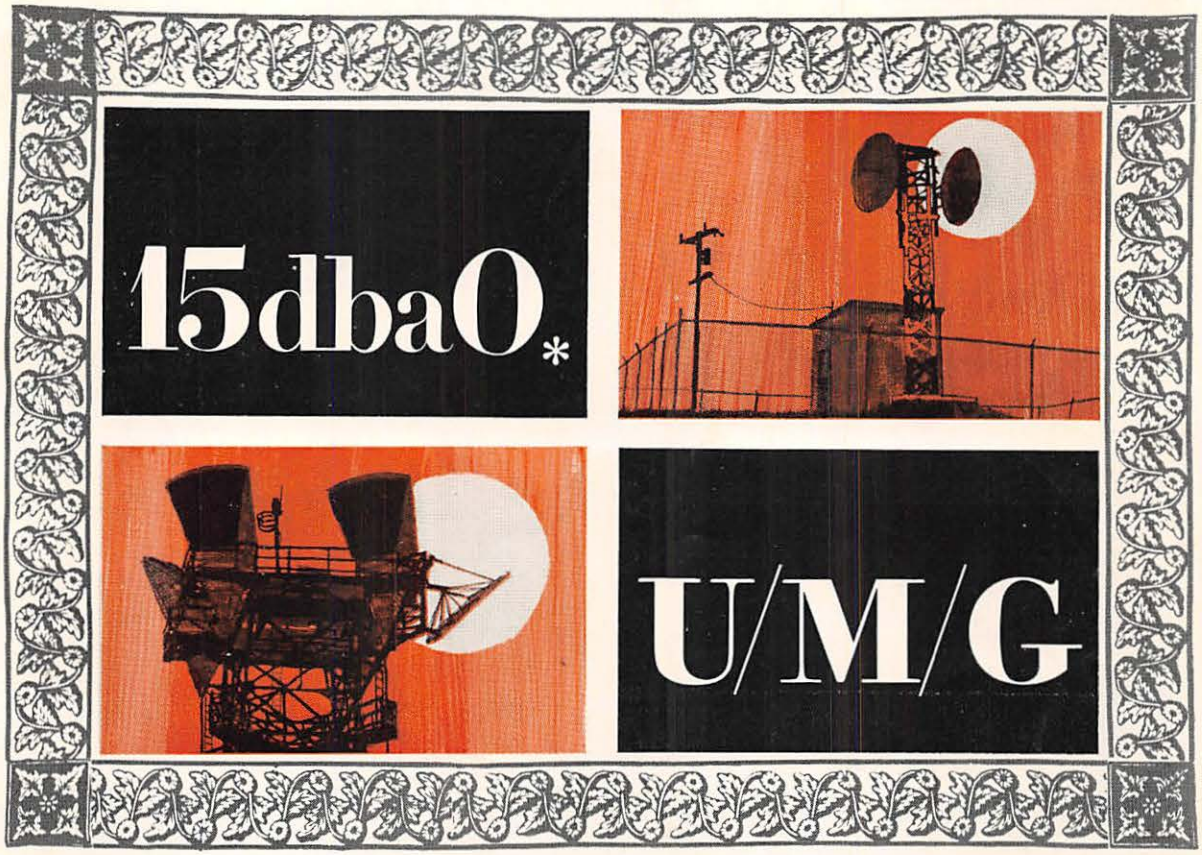

Proven field performance is your best guarantee

Are you getting better than 15 dbaO* in your worst multiplex channel? Users of Collins 1-watt Universal Microwave Group equipment are (without emphasis for 600 channel loading), and with typical noise performance of 12 to 13 dbaO! ■ Most guarantees look good on paper. But if you miss your performance objectives during installation or can't hold them in daily operation, there is usually little you or your microwave supplier can do about it. ■ Compare Collins field performance figures with your objectives. Then let us show you what Collins 4-gc, 6-gc, and 11-gc 1-watt, remodulating microwave can do for you. ■ After all, isn't proven field performance the best proof you can have that Collins U/M/G equipment can help you meet and hold your noise performance objectives? Call, write or wire Collins Radio Company, Microwave Marketing, Dallas, Texas, Area Code 214, AD 5-9511. ■ *Per path as determined by standard noise loading test techniques with proper systems engineering and adequate antenna systems.

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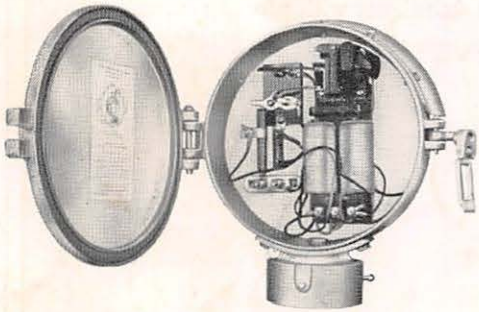
ALUMINUM HIGHWAY CROSSING BELLS

with BELL STEEL GONGS TYPES 222 AND 1275

WEIGH 40% LESS THAN CAST-IRON BELLS

These new Western Aluminum Highway Crossing Bells, Types 222 and 1275, are lighter in weight and as reliable as ever. Specifically: the Type 222 Aluminum Bell weighs only 29 lbs., as against 48 lbs. for that of cast iron, and the Type 1275 in Aluminum weighs only 20 lbs. against 32 lbs. for the cast iron. Aluminum parts include: housing, cover, rainshield, and mounting socket. These changes make quite a difference in weight. But there's no difference in quality and tone: for they have the same dependable mechanism as before; as always, parts are fitted snugly to assure bug-, dust- and weather-proofing, and *the gong is still made of bell steel.*



TYPE 222: Twelve-inch bell steel gong; 200 strokes per minute; 6 to 600 volts D.C., as specified.

TYPE 1275 (not shown): Same as Type 222, except with eight-inch bell steel gong (softer tone); 225 strokes per minute; 6 to 16 volts D.C.

Making greater use of aluminum throughout, these Bells are complementary for use on Western's Aluminum Highway Crossing Signal, TYPE A-479-A, with Flashing Light, TYPE 970-201, on the Aluminum Cantilever Assembly, TYPE A-740, also on Model 10 Gates.

Over 100,000 Western Bells in use.

For additional information on bells and bell mechanisms, see your WRRS Catalog, Section B, or write to us:

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